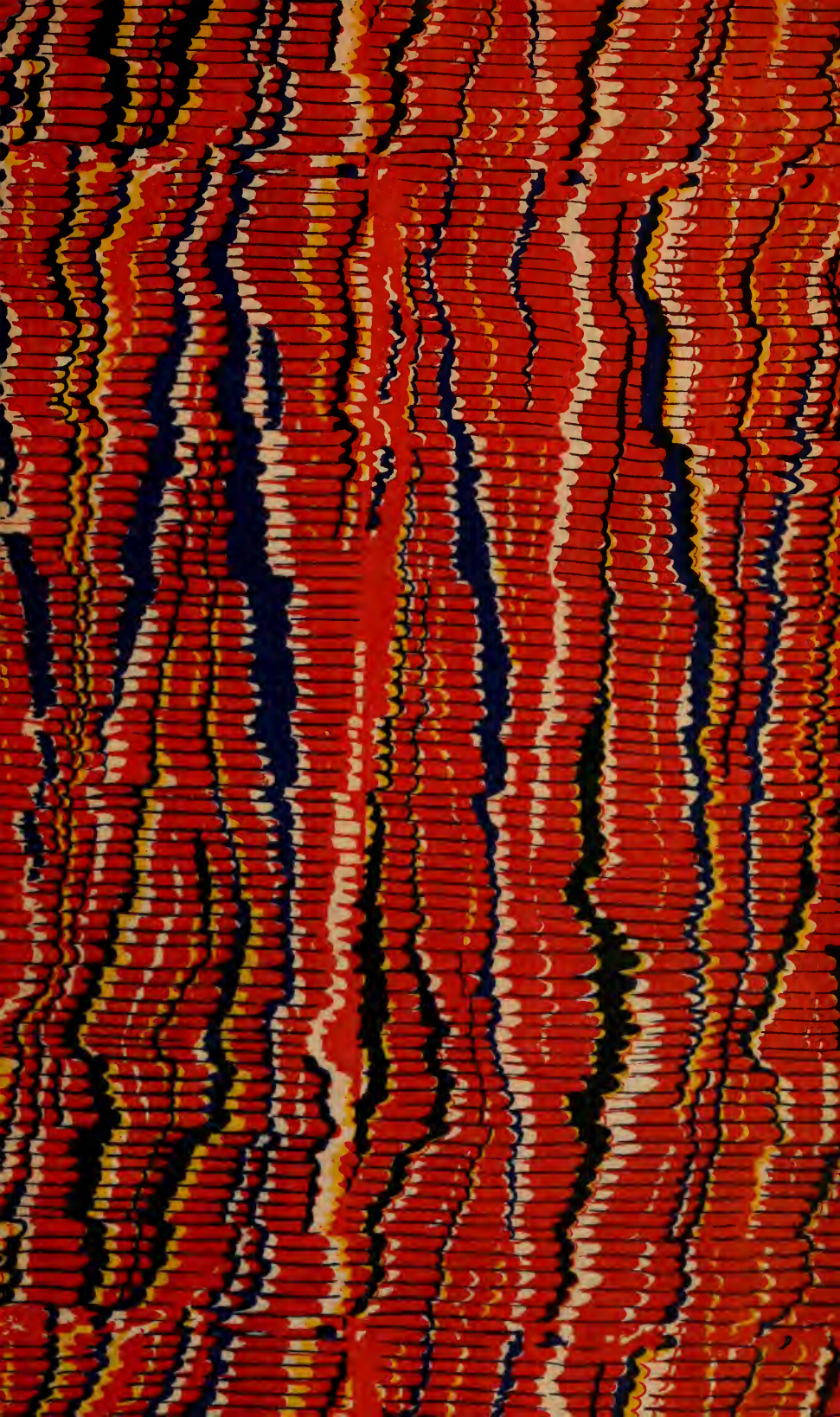

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DIV. INSECTS

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No. 204

Contribution from the Bureau of Entomology, L. O. Howard, Chief,

May 21, 1915.

REPORT ON THE GIPSY MOTH WORK IN NEW ENGLAND.[1]

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In Charge of Gipsy Moth and Brown-Tail Moth Work.

INTRODUCTION.

On March 1, 1913, the gipsy-moth work conducted by the Bureau of Entomology, U. S. Department of Agriculture, was reorganized, and the writer was placed in charge under the direction of the chief of the bureau.

The object of this Federal work is to use every measure possible to prevent the spread of the gipsy moth and the brown-tail moth[2] to uninfested parts of the United States.

The main office, which is maintained at 43 Tremont Street, Boston, Mass., furnishes quarters for the men in charge of the main projects and the necessary clerical force. The Gipsy Moth Laboratory, which serves as headquarters for the experimental work, is located at Melrose Highlands, Mass., although one branch of this work is conducted at the Bussey Institution at Forest Hills, Mass. During the past two years a summer laboratory has been maintained for special experiments at Worcester, Mass. A storehouse is located at Melrose Highlands, Mass., where the necessary tools and equipment are stored and repaired.

The work is divided into two distinct lines: (1) Field work, consisting of scouting, and applying hand methods for controlling these insects, as well as a thorough inspection of the plant products shipped from the infested area, and (2) experimental work, which includes the introduction of parasites and natural enemies, together with careful studies of the food plants and other factors, in order to devise more efficient and effective methods of control, as well as an investigation of the relation of silviculture to the gipsy-moth problem. A

[1] This publication is prepared to show the different lines of work which are being taken up and the results that have been secured.

[2] The life history, habits, and methods for controlling these insects have been published in Farmers' Bulletin 564, U. S. Department of Agriculture.

general outline of the problems and investigations and the different activities of the work has already been published[1] in the Journal of Economic Entomology.

During the fiscal year which ended June 30, 1914, an average of 275 men was employed. The greater number were engaged in field operations, but a force of approximately 40 men were employed on different phases of experimental projects.

EXPERIMENTAL WORK.

In carrying on measures for the control of any insect pest it is necessary to conduct many experiments in order to determine the means which are most feasible for reducing the damage. For more than 20 years experiments have been carried on more or less continuously by the State of Massachusetts and other States to which the gipsy moth has spread, as well as by the Bureau of Entomology, for the purpose of perfecting field measures for holding the insect in check, and from time to time improvements have been made which have reduced the cost of handling infested areas. Spraying machinery has been developed so that at the present time it is entirely practical to treat large areas at a moderate cost. The banding of trees with tanglefoot has largely replaced the use of burlap bands and reduced the cost of this method of treatment. In fact, so much work has been done along these lines that the best methods of treatment are well understood and practiced in the areas where the gipsy moth is prevalent. Minor improvements are being made from time to time but in general satisfactory methods of hand suppression have been adopted.

In 1905, when the Federal gipsy-moth work was being organized, it was considered very necessary and desirable to introduce the parasites and natural enemies which occur in foreign countries of both the gipsy moth (*Porthetria dispar* L.) (Pl. I) and the brown-tail moth (*Euproctis chrysorrhoea* L.) (Pl. II). The idea was prevalent that by securing and liberating these natural checks on the increase of these species, it would be possible greatly to reduce the damage, and it was hoped that the parasites would bring the pests as well under control as is the case in Europe. Accordingly arrangements were made by Dr. L. O. Howard, Chief of the Bureau of Entomology, for the collection of a large amount of parasitic material in various European countries, and later similar arrangements were made with entomologists in Japan. This work was carried on for the first five years in cooperation with the State of Massachusetts. Several agents of the Bureau of Entomology have been sent to Europe on different occasions to investigate conditions and forward to this country as large an amount of parasitized material as could be collected. For two seasons this work was conducted by Mr. W. F. Fiske, who was assisted in the summer of 1912 by Mr. L. H. Worthley. Various

[1] Jour. Econ. Ent., v. 7, No. 1, p. 83-87, Feb., 1914.

assistants and collectors were engaged to obtain parasitized material which was forwarded to the Gipsy Moth Laboratory at Melrose Highlands, Mass. After the completion of the foreign work in 1912, it appeared that not only were the parasites, and a contagious disease known as the "wilt," prime factors in controlling the gipsy moth in Europe, but in addition to these a pronounced obstacle to the increase of the pest arose from the fact that forest conditions, particularly in Germany, furnished in the main unfavorable food for the caterpillars. The observations indicated that this factor, in addition to the natural enemies already mentioned, was responsible for rendering the gipsy moth of slight importance to forest growth except at periodic intervals.

In 1912 a number of areas were under observation by Mr. Worthley in the forests of Germany, and at that time the infestation was severe. Deciduous trees in these areas were defoliated and in some cases many trees completely denuded of foliage. Similar studies were made by Mr. Fiske in Italy, where a few infestations were found which were more serious, if possible, than those observed in the German forests. During the summer of 1913 no agent of the bureau was engaged in making foreign observations on the gipsy moth. It seemed best in the spring of 1914 to have the areas in Germany revisited for the purpose of determining the result of the previous infestations and to secure data on the increase or the decrease of the species. Accordingly, early in the spring of that year, Dr. John N. Summers, who for a number of years had been in general charge of the parasite work at the Melrose Highlands Laboratory, was detailed to visit the areas mentioned and to secure all the data possible on the fluctuations of the gipsy moth, as well as to obtain parasitic material for shipment to this country, in case it could be found in collectible quantities. The result of this work has been reported by Dr. Summers, and it appears that in no place in Germany where the insect was reported in 1912 was there a severe or even moderate infestation in 1914. It was impossible, therefore, to obtain parasitized material, and in most cases the insect was so rare that little data beyond the mere fact that it still existed in the areas could be secured.

About the middle of June a report was received that a heavy infestation of the gipsy moth occurred in the Province of Bereg, Hungary. This information was received from Dr. Josef Jablonowski, and Dr. Summers was instructed to take up his investigations in that region. Unfortunately it was impossible for him to arrive in the infested forest until after the feeding of the caterpillars was finished and most of the eggs for the new brood of moths had been laid. Parasites were not present to any marked extent at this time, which was not surprising, owing to the fact that the observations were made too late in the season. Some evidence was secured that the wilt disease was present in the area, but a fairly good increase of the species was noted except at points where the trees had been completely denuded and where the caterpillars had died from starvation or had moved to

adjoining tree growth in search of food. Dr. Summers estimates that not less than 5,000 acres were almost completely defoliated in the forests in Hungary where he made his observations. The growth consisted entirely of hardwoods; the oak predominating, and a species of Carpinus, beech, and maple occurring in the order mentioned. A few elm trees were also present.

The results of the European investigations carried on during the past few years, aside from furnishing a good supply of parasitic species, has proved beyond question that as far as the forests are concerned the character of the growth is of prime importance from a gipsy-moth point of view. Coniferous forests predominate in Germany, and these are not injured by the gipsy moth. The deciduous forests in that country are not large, and the injury is periodical and severe. In Hungary large deciduous forests are present and the infestation is more or less common from year to year. Severe defoliation usually continues for about three years before a marked decrease of the moth is observed, and then a few years pass before another outbreak is noticed. This information, with certain data which have been collected in this country for the past few years relative to the increase or decrease of the gipsy moth under New England forest conditions, together with a careful study of the feeding habits of the gipsy-moth caterpillar in all its stages on the various species of tree growth, and the beneficial influence which is being felt to a greater extent each year as a result of the increase of the parasites and natural enemies of the moth and the severity of the wilt disease, all point the way to more effective methods of handling the gipsy-moth problem.

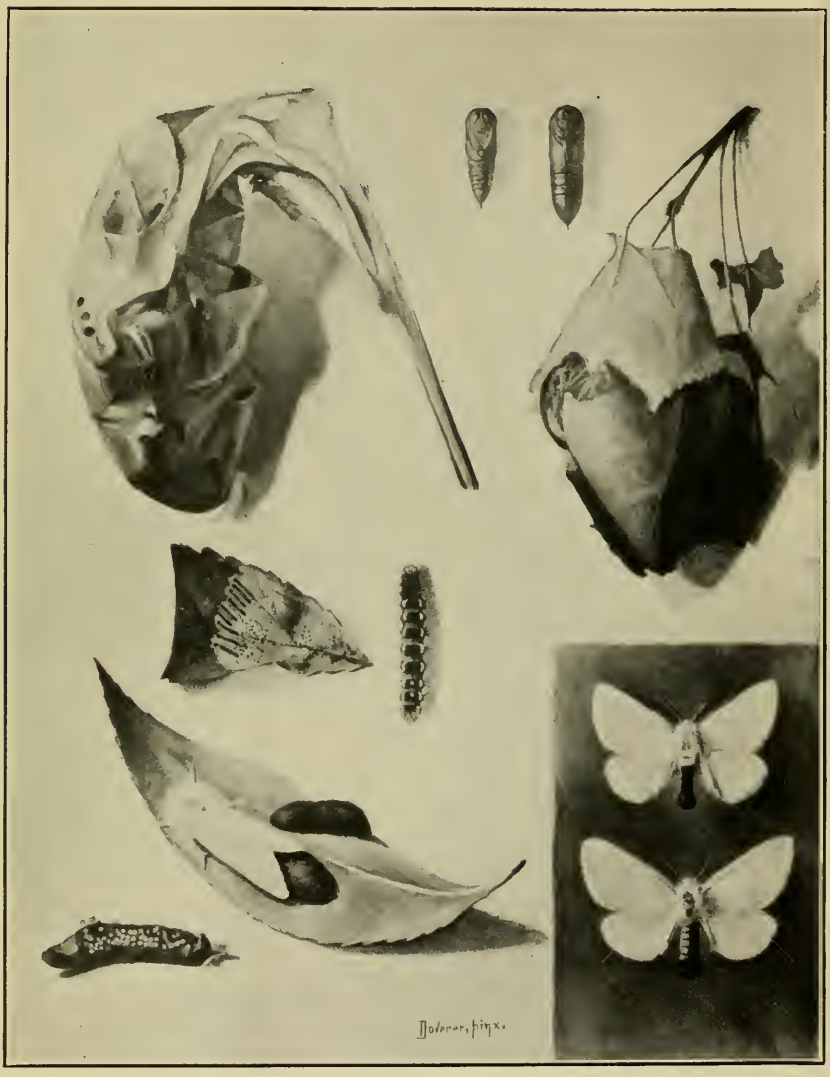
The different phases of the experimental work, as it is being carried on, will be touched upon briefly in order to indicate the changed conditions which are being brought about in the infested area in New England.

PARASITE WORK.

As has already been stated, the first attempts to introduce the parasites and natural enemies of the gipsy moth and brown-tail moth were begun in 1905. In all more than 30 enemies of these insects, which are present to a greater or less extent in their native homes, have been introduced into New England. More than half of the species have been received in sufficient numbers so that colonies could be liberated under field conditions, and they have had an opportunity to demonstrate their ability to withstand climatic conditions and to become established in this country. As should be expected, a large number of the species have failed to survive. A few have been recovered from year to year, showing that while they have the ability to maintain themselves, they have not yet been able to increase to a sufficient extent to become a useful factor in controlling their hosts. A few species have become established and are increasing satisfactorily. In fact, some of them are making sufficient headway so that they have already become a very appreciable

THE GIPSY MOTH (PORTHETRIA DISPAR).

Upper left, male moth with wings folded; just below this, female moth with wings spread; just below this, male moth with wings spread; lower left, female moth, enlarged; top center, male pupa at left, female pupa at right; center, larva; on branch, at top, newly formed pupa; on branch; just below this, larva ready to pupate; on branch, left side, pupæ; on branch, center, egg cluster, on branch, at bottom, female moth depositing egg cluster. All slightly reduced except figure at lower left. (From Howard and Fiske.)



THE BROWN-TAIL MOTH (EUPROCTIS CHRYSORRHOEA).

Upper left, hibernating web; just below this, small larvæ feeding at left, larger larva at right; just below this, female moth depositing eggs at left, egg mass at right; lower left, egg mass with eggs exposed; top center, male pupa at left, female pupa at right; upper right, cocoon incased in leaves; lower right, male moth above, female moth below. All slightly reduced. (From Howard and Fiske.)

factor in reducing the infestation of the gipsy moth even under our adverse food-plant conditions. The most valuable species will be mentioned briefly in order to give an idea of their habits.

FIG. 1.—*Anastatus bifasciatus:* Adult female. Greatly enlarged. (From Howard.)

Two species of minute hymenopterous parasites which attack the eggs of the gipsy moth have become established in New England. One, *Anastatus bifasciatus* Fonsc. (fig. 1), occurs in Europe and Japan, and although only one brood of this insect is reproduced each

FIG. 2.—*Schedius kuvanae:* Adult female. Greatly enlarged. (From Howard.)

season, it has succeeded in maintaining itself and increasing in practically every locality in which it has been liberated. The other species, *Schedius kuvanae* How. (fig. 2), was imported from Japan.

A brood of this species develops under favorable weather conditions in about four weeks. The first brood appears in August and the insect continues to breed until cold weather sets in. Owing to the fact that several broods develop in a single season, the insect increases very rapidly. It can be reared in the laboratory for the purpose of colonization, and this work is being done each year. Unfortunately the insect does not always survive the winter in good condition, so that its occurrence in the colonies where it is liberated is by no means as uniform as that of Anastatus.

Apanteles lacteicolor Vier. (fig. 3) is a small hymenopterous parasite which deposits its eggs in the small caterpillars of the brown-tail moth in August. The eggs of the parasite hatch in the body of the small caterpillar, but development is very slow during the fall. Caterpillars that are attacked in this way feed and enter the hibernating web with their more fortunate comrades. They pass the winter and emerge with the others early in the spring. As soon as they have become active and begin feeding the Apanteles larva also begins feeding and by the time the caterpillar is about one-fourth of an inch long this internal parasite has become large enough to destroy it. The Apanteles larva then makes its way from the body of the caterpillar, forms a cocoon (Pl. III, fig. 1), and early in June the adult parasite emerges. This is the time of year when small caterpillars of the gipsy moth are feeding, and the parasites attack these caterpillars and pass through one generation with the gipsy moth as a host.

FIG. 3.—*Apanteles lacteicolor:* Adult female and cocoon. Much enlarged. (Original.)

Another species which attacks both the gipsy and brown-tail moth caterpillars is a parasitic fly known as *Compsilura concinnata* Meig. (Pl. III, fig. 2). This insect is about the size of the house fly, although its habits are strictly those of a caterpillar parasite. Early in the spring the female fly deposits a small maggot in the body of the larva of the brown-tail moth which feeds inside the body of the caterpillar and becomes full-grown early in June. At this time the maggot burrows through the epidermis of the host and forms a puparium from which, in about a week, the adult fly emerges. This brood attacks the gipsy-moth caterpillars, the adult

flies emerging early in July. One or more broods may follow before cold weather in case native larvæ are at hand to serve as hosts.

A species of Apanteles (*A. melanoscelis* Ratz.), which was received in small numbers from Italy in the summer of 1912, was liberated near the laboratory at Melrose Highlands, Mass. It is double-brooded, both generations being passed on gipsy-moth caterpillars. This species has maintained itself since its introduction and promises to be a most valuable addition to the enemies of the gipsy moth. It has not been imported or recovered in sufficient numbers from the colony liberated in this country so that other colonies could be established, but is considered a very valuable species.

The Calosoma beetle (*C. sycophanta* L.) (Pl. IV), while not strictly a parasite, is at the present time doing more effective work against the gipsy moth than any single introduced species. This large green beetle hibernates in the ground during the winter and emerges about the first of June. It feeds on the caterpillars and pupæ of the gipsy moth and brown-tail moth, as well as on such native species as it may find. These beetles climb trees and are continuously searching for food. They live two or three years and after midsummer burrow into the ground where they remain during the winter. On the average, 100 eggs are deposited in the ground annually by each female. The beetle larvæ hatch in about a week. They are proficient tree climbers and feed constantly on the caterpillars and pupæ of the gipsy moth or other insects until they become full grown about the middle of July. This species has increased and spread in a most satisfactory manner, and has made great inroads on the gipsy moth in many localities. Both the beetles and the larvæ attack the caterpillars of the brown-tail moth, so that double benefit results.

Another parasite, one which attacks the brown-tail moth only, is a hymenopteron known as *Meteorus versicolor* Wesm. It has become well established, but is seldom found in great numbers. It is possible that this species may increase rapidly later on, but at the present time it does not appear to be as beneficial as those that have previously been mentioned. Several species of introduced tachinid flies are recovered occasionally, but in such small numbers as to indicate that they are not at the present time doing effective work.

An enormous amount of careful study and a large number of detailed experiments have been carried on in order to determine the life histories, habits, and utility of the different species which have been introduced. It has been necessary from time to time to develop new methods of handling these species in order to get the data desired, and practically all the equipment and breeding devices

used at the laboratory are of original design and have been constructed for the purpose of furthering the gipsy-moth investigations. Much valuable information of a biological nature has been secured which is not only of direct value to the parasite phase of the gipsy-moth work but has been found useful in connection with insect problems in various parts of the country.

RECENT COLONIZATIONS AND RECOVERY OF IMPORTED PARASITES.

During the past two or three years careful investigations have been carried on to determine the increase and spread of the different parasites. In the summer of 1914 this work was in charge of Mr. S. S. Crossman. As large a number as possible of the different species have been liberated in the remote parts of the infested area for the purpose of securing the establishment of these valuable species over the entire territory at the earliest possible date. In the fall of 1913 *Anastatus bifasciatus* was recovered from 41 towns and the parasitism in the collections secured averaged about 30 per cent. From one collection over 43 per cent of the eggs had been destroyed by this insect. As a result of the collection made during the winter, 1,561 colonies of this species, totaling 1,561,000 specimens, were liberated; 1,047 of the colonies were placed in 12 towns in Massachusetts and 514 in three towns in New Hampshire. This insect spreads very slowly, hence it is necessary to liberate many colonies. The plan which is being used is to place a sufficient number of colonies in a town so that no further colonization in that town will be necessary. The work on this insect required the collection in the fall of 1913 of about 7,500 gipsy-moth egg clusters and these were secured from over 100 selected localities.

In the fall of 1913, 33 towns were colonized with *Schedius kuvanae.* The number of colonies placed in a town varied from 1 to 10, depending on the gipsy-moth infestations. Most of the colonies were liberated in the southern part of the infested territory in Massachusetts, as it was believed that this section would be favorable for the survival of the species during the winter. In all 110 colonies were liberated, containing over 375,000 individuals. This species spreads more rapidly than Anastatus, so it is not necessary to place as many colonies in a given area. Over 14,000 gipsy-moth egg clusters were collected from about 100 selected localities within the area bounded by Exeter, N. H., and Berlin, Bolton, and Mashpee, Mass. This material was used at the laboratory to secure records of the percentage of parasitism in colonies that had been liberated in previous years.

The spring of 1913 was very favorable for *Apanteles lacteicolor,* and it was recovered from 69 towns. This was the result of collections of 92,000 brown-tail moth webs, a supply coming from every one of

FIG. 1.—COCOONS OF APANTELES LACTEICOLOR IN MOLTING WEB OF THE BROWN-TAIL MOTH. (ORIGINAL.)

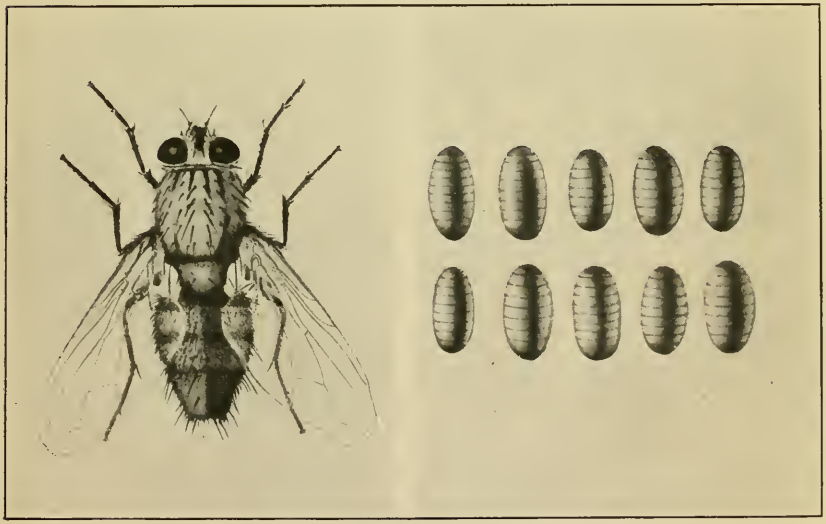
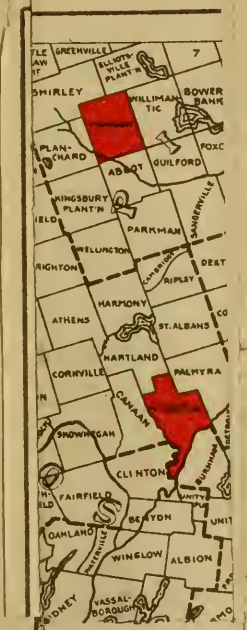


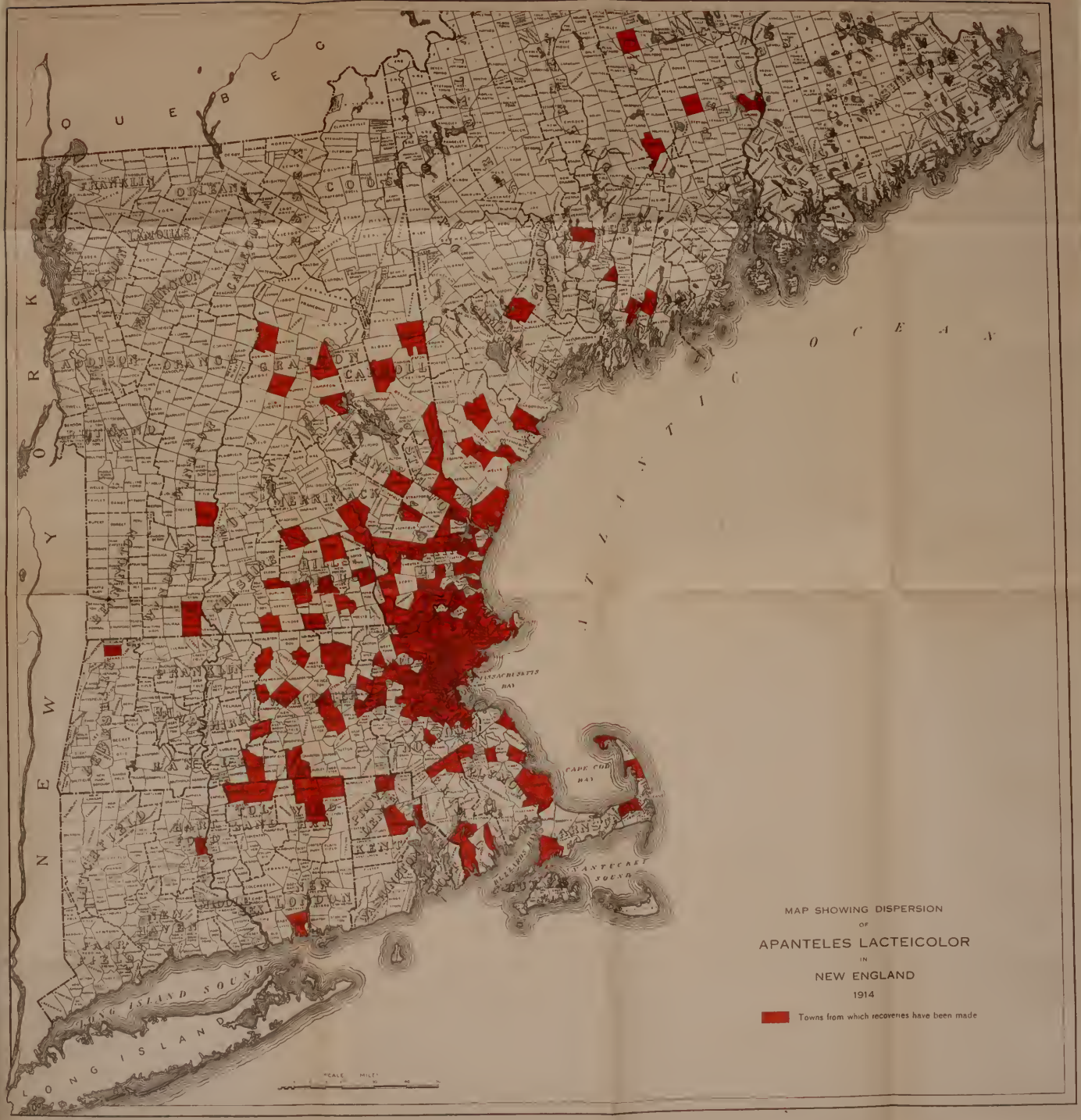
FIG. 2.—THE COMPSILURA FLY (COMPSILURA CONCINNATA): ADULT FLY, MUCH ENLARGED, AT LEFT; PUPARIA, ENLARGED, AT RIGHT. (ORIGINAL.)

THE CALOSOMA BEETLE (CALOSOMA SYCOPHANTA).

Upper left, eggs; lower left, adult beetle feeding on gipsy moth caterpillar; upper right, gipsy moth pupæ destroyed by Calosoma larvæ; center, Calosoma larva, ventral view; right center, Calosoma larva, dorsal view; lower right, Calosoma pupa in cavity in ground. (From Howard and Fiske.)

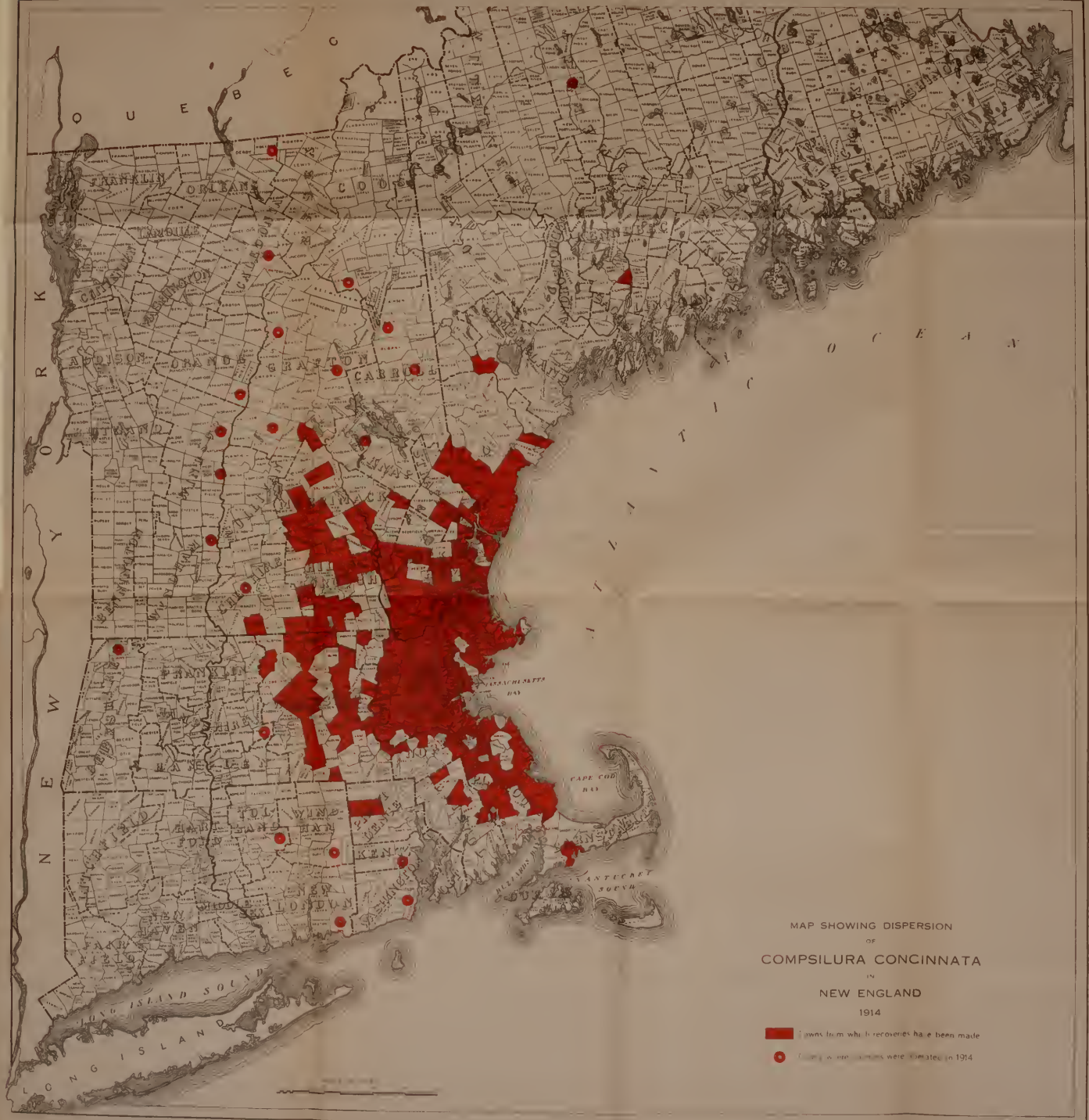
he New England States. Fifty-six colonies were liberated in 48





MAP SHOWING DISPERSION
OF
APANTELES LACTEICOLOR
IN
NEW ENGLAND
1914

Towns from which recoveries have been made


QUEBEC
FRANKLIN
ORLEANS
ESSEX
CALEDONIA
WASHINGTON
ORANGE
GRAFTON
CARROLL
STRAFFORD
MERRIMACK
HILLSBOROUGH
CHESHIRE
SULLIVAN
SAINT LAWRENCE
HERKIMER
MONTGOMERY
FULTON
SARATOGA
WASHINGTON
RENSSELAER
COLUMBIA
GREENE
ALBANY
SCHOHARIE
DELAWARE
OTSEGO
CHENANGO
MADISON
ONEIDA
HAMILTON
FULTON
MONTGOMERY
SCHENECTADY
SCHOHARIE
OTSEGO
CHENANGO
BROOME
TIOGA
TOMPKINS
CORTLAND
ONONDAGA
CAYUGA
SENECA
SCHUYLER
CHEMUNG
STEUBEN
ALLEGANY
CATTARAUGUS
ERIE
NIAGARA
ORLEANS
GENESEE
WYOMING
LIVINGSTON
ONTARIO
YATES
WAYNE
MONROE
WAYNE
ONTARIO
SENECA
CAYUGA
TOMPKINS
CORTLAND
CHENANGO
TIOGA
BROOME
DELAWARE
SULLIVAN
ORANGE
PUTNAM
DUTCHESS
ULSTER
GREENE
COLUMBIA
RENSSELAER
SARATOGA
WASHINGTON
WARREN
ESSEX
CLINTON
FRANKLIN
ST. LAWRENCE
LEWIS
JEFFERSON
OSWEGO
MADISON
ONEIDA
HERKIMER
FULTON
HAMIL

the New England States. Fifty-six colonies were liberated in 48 towns, a total of over 76,000 cocoons being placed in the field. During the winter of 1913–14 collections of brown-tail moth webs were made in 72 towns scattered over the infested area in New England. The recovery of the parasite indicates that it has become established as far north as Monson, Me.; west as far as North Adams, Mass.; and south as far as Waterford, Conn. About 2,500 cocoons were liberated in the spring of 1914 in three of the Connecticut Valley towns in Vermont. Our work on this species was supplemented by cooperative work which was carried on by Prof. W. C. O'Kane, State entomologist of New Hampshire. From collections made by his assistants he was able to colonize Apanteles in 11 towns, 1,000 specimens being put in most of these colonies. Similar work is carried on in cooperation with the gipsy-moth laboratory by Maj. E. E. Philbrook, State moth superintendent of Maine, but a definite statement of the number of colonies liberated can not be given at this time. An arrangement was made during the fall of 1913 to continue cooperative parasite work between the laboratory and the entomologist of the Dominion of Canada, Dr. C. Gordon Hewitt. In the spring of 1914 he detailed one of his assistants, Mr. L. S. McLaine, to take up work in Massachusetts, using the gipsy moth laboratory as headquarters. Mr. McLaine secured several assistants, and as a result of his efforts about 1,000 Apanteles cocoons were sent to the brown-tail moth infested area in New Brunswick for the purpose of colonizing the species. Similar efforts were made the previous year and colonies were liberated in New Brunswick and Nova Scotia, and in several of these places the species survived the winter of 1913. (Pl. V.) In general it should be said that the winter of 1913–14 resulted in a marked decrease in the abundance of Apanteles. An unusually high mortality of caterpillars in the brown-tail webs accounts for this decrease. The exact cause of the mortality of the brown-tail moth caterpillars can not be definitely stated, but it seems to be attributable to an unusually severe winter, the presence to a greater or less extent of internal parasites in the caterpillars, and the effects of the brown-tail fungus, a disease which also affects the larvæ of this species.

The parasitism of the gipsy moth by *Apanteles lacteicolor* was not nearly as high in 1914 as during the previous year, and was of course a direct result of the failure of the brown-tail moth caterpillars to bring through the first generation of the parasite.

During the summer of 1913 *Compsilura concinnata* was recovered from 54 new towns. Eleven of these were in Maine, 14 in New Hampshire, and 29 in Massachusetts. In the summer of 1914 this insect was found in 44 new towns—2 in Maine, 21 in New Hampshire, 20 in Massachusetts, and 1 in Rhode Island. It is possible that

Compsilura is present in more localities in Maine, but we have been unable to secure definite records to that effect. The following table is interesting, as it shows the general rate of dispersion of this parasite. The spread recorded is based on distance from Melrose Highlands, Mass., and is mostly due to natural spread, although a few small colonies have been liberated outside of the area where the species was known to occur in 1913.

TABLE I.—*Dispersion of Compsilura concinnata. Distance recovered from Melrose Highlands, Mass.*

	1913	1914
From Melrose Highlands:	*Miles.*	*Miles.*
North	75	100
Northeast	100	130
South	50	50
Southwest	40	55
West	50	65
Northwest	70	80

It is undoubtedly true that this species is now present over an area which would be represented by connecting the points indicated by the directions and distances given in the table for 1914. (Pl. VI.) Four thousand five hundred and sixty-five Compsilura were liberated in 10 new towns in 1913 and 10,000 were placed in 21 new towns in 1914, as follows: Eight in New Hampshire, 5 in Vermont, 2 in Massachusetts, 2 in Rhode Island, 3 in Connecticut, and 1 colony was forwarded to a substation of the Bureau of Entomology at Koehler, N. Mex., in order to test the value of this species as an enemy of the range caterpillar (*Hemileuca oliviae* Ckll.), an insect which is causing enormous damage to the grazing lands in that State. In addition to the number of specimens of this species colonized in 1914, about 5,000 were secured by Mr. McLaine and shipped to New Brunswick; about 3,000 were secured by Mr. R. S. Ferguson, assistant in the moth department of the State of Maine, who, with several assistants, were collecting for the purpose of establishing colonies in that State, and over 2,500 were collected and colonized by Prof. O'Kane's assistants in New Hampshire.

Three hundred and sixty-five sample collections of gipsy-moth larvæ which were secured during the summer of 1914 from scattered localities in Maine, New Hampshire, Massachusetts, and Rhode Island, consisted of over 99,000 caterpillars. This material required the use of over 500 rearing trays at the laboratory and the constant attention of several assistants to feed the larvæ in each tray and record the parasitism, mortality, and other data.

Based on 25 collections of gipsy-moth larvæ taken at widely scattered points in the gipsy-moth-infested area and aggregating 46,000

specimens, an average of 20 per cent of parasitism by Compsilura was found to exist. Several large single colonies showed a degree of parasitism ranging from 40 to 50 per cent. The results secured with this species during the summer of 1914, based on the number of parasites obtained from the collections, indicate that the distribution of this insect is more likely to be local than general, since in areas where it was abundant in the summer of 1913 it was recovered in very small numbers in 1914, in spite of the fact that a moderate infestation was present during the latter year.

Apanteles melanoscelis, a species already referred to, is showing considerable promise. As high as 19 per cent of the second stage gipsy moth larvæ collected at Melrose Highlands during the summer of 1914 were parasitized. This species was recovered from two new towns this year, namely, Stoneham and Saugus.

Considerable additional data have been secured from other imported parasites which have been colonized in this country and have survived in more or less numbers. The details are not given, however, inasmuch as it has not been demonstrated thus far that they are of particular value as parasites of either the gipsy moth or the brown-tail moth.

Pteromalus egregius Först. has been recovered in small numbers from many parts of the territory infested by the brown-tail moth. The larva of this insect works as an external parasite of the small brown-tail moth caterpillars in the webs. *Monodontomerus aereus* Walk., a parasite of gipsy and brown-tail moth pupæ, is known to occur throughout most of the area infested by these insects. It has been reared in small numbers from tachinid puparia and undoubtedly has other unrecorded hosts.

Calosoma sycophanta has been found during the summer of 1914 over a much wider area than that previously recorded (Pl. VII). Owing to the ease with which the beetles and their larvæ could be collected in the field it has been possible to liberate 37 colonies in New Hampshire, Massachusetts, Rhode Island, and Connecticut. These were placed outside the area where the species was previously known to occur. In addition, colonies of Calosoma have been liberated in Maine and New Hampshire by State officials. Colonies have been liberated in New Brunswick, Nova Scotia, and Quebec as a result of collections made by Mr. McLaine and his assistants, and 1,700 specimens were collected by Mr. H. E. Smith and forwarded to Kochler, N. Mex., to test their value as an enemy of the range caterpillar.[1]

[1] This work was carried on by arrangement with Mr. F. M. Webster, who is in charge of the Cereal and Forage Crop Insect Investigations of the Bureau of Entomology.

As a result of the Calosoma scouting work carried on during July and August, 1914, it has been found that this species exists in 18 towns in Maine, 93 in New Hampshire, 170 in Massachusetts, 3 in Rhode Island, and 2 in Connecticut. Data concerning this insect obtained during the present year indicate that the species is able to maintain itself in considerable numbers in areas where the gipsy-moth infestation is slight and that as a rule the species continues to be abundant after it once becomes established in a locality. Owing to the well-known habits of the beetles in migrating considerable distances, it was thought that territory with light infestation would be deserted in favor of areas where caterpillars occurred in abundance. This does not prove to be the case and it is another feature which increases the value of this beneficial insect.

The table below shows the colonization of the principal parasites during 1913 and 1914:

TABLE II.—*Colonization of natural enemies in 1913 and 1914.*

Species.	Number of colonies liberated.		Number of individuals liberated.		Towns where colonies were placed.	
	1913	1914	1913	1914	1913	1914
Anastatus bifasciatus[1]	1,500	1,561	1,500,000	1,561,000	[2] 42	15
Schedius kuvanae	110	502	352,000	2,083,254	33	111
Apanteles lacteicolor [1]	56	14	76,000	13,119	48	14
Compsilura concinnata [1]	10	28	4,565	23,638	10	26
Calosoma sycophanta [1]	45	49	6,175	8,104	42	38

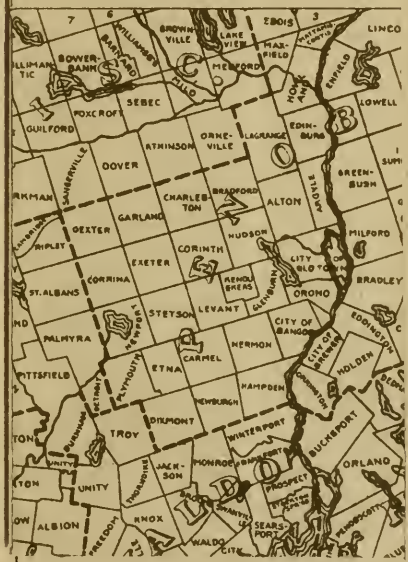
[1] A part of the collections and colonization were made by cooperative arrangements with the State officials of Maine and New Hampshire, with the Dominion Entomologist of Canada, and with Mr. F. M. Webster of this bureau.

[2] In many of these towns only a few colonies were liberated.

The results of the work accomplished by introduced parasites of the gipsy moth during the past year have been excellent. It is true that the increase of *Apanteles lacteicolor* has been seriously retarded but the other species have given a good account of themselves. The fact that Compsilura and Calosoma are becoming established in the remote parts of the area infested with the gipsy moth and are able to maintain themselves under these conditions is very encouraging, as the work of these species will tend to reduce the infestation and be an important factor in preventing the spread along the outside border.

WILT-DISEASE INVESTIGATIONS.

In connection with the parasite work and having a distinct influence on the increase of the gipsy moth in the field, an elaborate series of experiments has been conducted by Mr. R. W. Glaser and several assistants for the purpose of securing information on the identity of the wilt disease (Pl. VIII) and the factors which are favorable to its increase in the field.



This species has been fou
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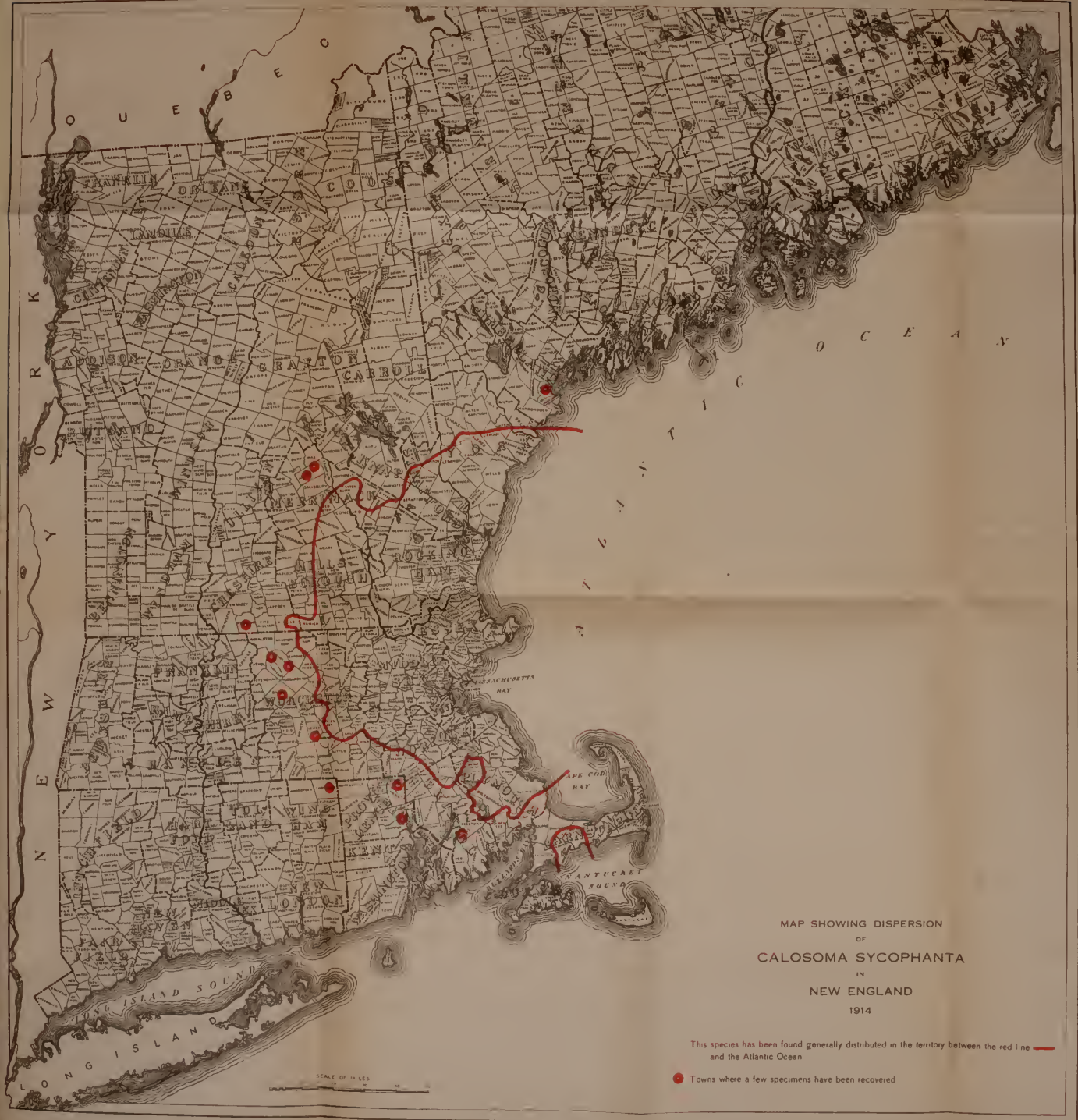


MAP SHOWING DISPERSION
OF
CALOSOMA SYCOPHANTA
IN
NEW ENGLAND
1914

This species has been found generally distributed in the territory between the red line and the Atlantic Ocean

Towns where a few specimens have been recovered

As a result of the Calosoma scouting work carried on during July

THE WILT DISEASE OF THE GIPSY MOTH. (ORIGINAL.)

Note the typical way in which these caterpillars hang when affected by this disease.

This work has been carried on at the Bussey Institution, Forest Hills, Mass., and a sublaboratory in charge of Mr. J. J. Culver has been maintained during the summer at Worcester, Mass., where special experiments have been conducted to determine the relation of favorable and unfavorable food plants to the development of the disease. A series of field experiments was also conducted in a selected area at Lunenburg, Mass., by Mr. A. W. Young and Mr. R. T. Webber, who made continuous observations in a limited area on the development of the disease under field conditions, with particular reference to the relation of temperature and humidity. Several other points were selected in Massachusetts where continuous temperature and humidity records were secured, as well as at the Lunenburg area, and a careful compilation of this data is expected to give information as to the weather conditions which are most favorable for the development of this disease.

For a number of years the wilt disease has been found in the field in nearly all places where heavy gipsy-moth infestation exists. During the last year or two it has occurred in light infestations and very few localities in the infested area are known where it is not found to a greater or less extent.

The results of the season's work indicate that the disease has been slightly less prevalent during the past summer than the previous year and this was particularly true during June and the first part of July. Cool weather prevailed at this time. Late in July the large caterpillars in many places were seriously affected, so that the increase of the gipsy moth was not as great as was anticipated early in the season.

The technical studies on the wilt disease are very difficult to conduct because it is almost impossible to secure healthy material for experimental purposes. The organism is believed to be a filterable virus and is so minute that it easily passes through the finest bacteriological filters that have yet been devised. It belongs to the same class of organism as yellow fever and a number of other contagious diseases, although all of these were, at one time, supposed to be caused by bacteria. The period when gipsy-moth caterpillars of moderate size are available for experiments covers about six weeks, and this adds to the difficulty of carrying on investigations on account of the limited time when material can be secured. During the past year it has been determined that the wilt disease, or a similar organism, affects eight of our common native caterpillars in addition to the gipsy moth. It is also known to attack the silkworm (*Sericaria mori* L.) and nun moth (*Porthetria monacha* L.), a fairly common European species which is very destructive to pine. Good results have been secured this year, but a large amount of work is necessary

in order to establish the essential facts concerning the identity of the organism and the conditions most favorable for its increase and development.

FOOD-PLANT INVESTIGATIONS.

As has already been pointed out, the species of tree growth have an important relation to the ability of the gipsy moth to increase and cause serious damage in the field. Nearly 20 years ago food-plant experiments were conducted in this country to determine the species upon which the gipsy moth would subsist, and a long list of food plants was published by Forbush and Fernald in their excellent book on the gipsy moth. Most of these experiments, however, were carried on by using large caterpillars and feeding them in jars or cages in the laboratory. At that time it did not seem important to determine whether there was variation in the feeding habits of the caterpillars in different stages. As early as 1908 it was observed and proven by an extensive field experiment that the first-stage caterpillars of the gipsy moth could not develop on white pine in the absence of other food. This naturally led to the question of unfavorability of other species to gipsy moth attack. In 1912 a careful series of food-plant experiments was begun. Mr. F. H. Mosher took charge of this work and has been furnished with a number of assistants during the feeding season. The feeding was carried on in individual trays, which were specially constructed for the purpose. One hundred first-stage caterpillars were placed upon a branch of foliage in each tray. In this way the feeding habits could be observed, the foliage renewed daily, and it was possible to determine which food plants were least subject to attack under laboratory conditions. Similar experiments were carried on with caterpillars in the succeeding stages. This work was continued in the summers of 1913 and 1914, so that up to the present time about 250 species of trees and shrubs have been tested.

As a result of these experiments some of the more common species are rated as follows:

I.—Species favored by the gipsy-moth larvæ in all stages:

Alder, speckled.[1]	Oak, black.
Ash, mountain.[1]	Oak, chestnut.
Aspen.[1]	Oak, post.[1]
Balm of Gilead.[1]	Oak, red.
Basswood.	Oak, scarlet.
Beech.	Oak, swamp white.
Birch, gray.[1]	Oak, white.
Birch, paper.	Poplar, big toothed.[1]
Birch, red.[1]	Shadbush.[1]
Boxelder.[1]	Willow.[1]
Larch.	Witch hazel.[1]

[1] Species of low commercial value.

II.—Species favored by the gipsy-moth larvæ after the first stage:

Chestnut.
Hemlock.
Pine, hard.[1]
Pine, red.
Pine, white.
Spruce, black.[1]
Spruce, Norway.
Spruce, red.
Spruce, white.[1]

III.—Species not favored by the gipsy-moth larvæ but capable of supporting it:

Beech, blue.[1]
Birch, black.
Birch, yellow.
Cherry, black.
Elm.
Gum, black.[1]
Hornbeam, hop.[1]
Maple, red.[1]
Maple, silver.[1]
Maple, sugar.
Pignut.
Sassafras.[1]
Shagbark.

IV.—Species unfavored by the gipsy-moth larvæ in all stages:

Arborvitæ.
Ash, black.[1]
Ash, white.
Butternut.
Cedar, red.[1]
Cedar, white.
Fir, balsam.[1]
Hackberry.[1]
Locust, black.
Locust, honey.
Sycamore.[1]
Tulip.

[1] Species of low commercial value.

During 1914 many food plants were tested which do not ordinarily occur in New England except when planted for ornamental purposes. They grow to a greater or less extent in other sections of the United States, and it was desired to make these tests in order to determine whether these plants would be seriously damaged by the gipsy moth in case it should spread from New England. The information is also useful as a guide to the method of treatment which should be applied in case a small colony should become established in some region outside the present infested area. During the first two summers that these experiments were carried on a sublaboratory was maintained at Worcester, Mass., where check experiments were conducted. The food-plant work is now nearly completed and the results will be brought together shortly for publication. In connection with these experiments it should be said that a large number of observations have been made in the field each summer relative to the favorability of different species of trees and undergrowth to gipsy-moth attack. This information serves as a check on the laboratory experiments which are carried on under artificial conditions. The observations in the field have in the main been made in definite areas, which were selected for an entirely different purpose and will be considered under the next experimental project.

EXPERIMENTS IN DETERMINING THE INCREASE OF THE GIPSY MOTH IN THE FIELD.

In view of the importance of parasites, disease, and unfavored food plants in reducing the increase of the gipsy moth, it seemed desirable to secure definite data on the normal increase of this insect in the field and the increase where these deterrent elements were present in varying degrees. The most feasible way to determine the increase is to compare the number of egg clusters in a given locality from year to year. In order to do this arrangements were made in the fall of 1911 to study field conditions in a systematic manner. About 250 areas which have been designated as "observation points" were selected throughout the infested area. This gave an opportunity for ascertaining the effect of latitude, seasonal variation, and altitude on the increase of the species. In selecting these points an attempt was made to secure as many pure stands of forest growth as possible; also, to obtain areas of mixed growth where the proportion of favored food plants varied. Areas were also secured where different species of parasites had been liberated and where the wilt disease had occurred abundantly or in a small amount during the previous year. The degree of infestation was also considered in making a selection and a number of points were obtained where the trees had previously been defoliated to check against some where no defoliation had resulted and the infestation was very light. After an area was selected a tree was marked for a center and a circle 100 feet in diameter was laid out. Each tree within the circle was numbered consecutively and a note made of its species, size, and condition. In the fall, as soon as the foliage had dropped, a careful count was made of the egg clusters on each tree. These results have been secured and tabulated as well as exact information relative to the number of egg clusters found on the ground and undergrowth. Records have also been kept on the condition of the trees from year to year, and the number of trees which died in each area has been carefully noted. The condition of the territory surrounding these points, as regards infestation, has also been noted. This work has been supervised by Mr. C. W. Minott, but it has not been carried on for a sufficient number of years to give all the exact information desired.

The following table gives the gross number of egg clusters found in the points each year, and will be of interest as indicating in a general way the severity of the infestation from 1910 to 1914.

It will be noted that 170 points are given in the table. The balance of the 250 which were originally selected have been discontinued, owing to destruction by fire, promiscuous cutting by the owners, or for other reasons. The area in the points aggregates 30.18 acres, and the surrounding territory which has been watched brings the total under observation up to 863.1 acres. For convenience, the

infested territory has been divided into five sections, and the towns in which the points were located are indicated on the accompanying map.

TABLE III.—*Gipsy moth egg clusters recorded in observation points, 1910–1914.*

Locations.	Number of points.	Egg clusters.				
		1910	1911	1912	1913	1914
Eastern New Hampshire and Maine	32	2,074	31,751	29,637	26,147	18,234
Western New Hampshire	33	14,885	23,032	28,618	9,603	13,228
Northern Massachusetts	34	29,399	47,419	30,345	17,603	31,316
Western Massachusetts	30	10,742	26,409	28,301	9,763	17,159
Southern Massachusetts	41	11,486	39,319	42,451	8,222	31,065
Area, 30.18 acres	170	68,586	167,930	159,352	71,338	111,002

The count of the egg clusters recorded under 1910 was made in the fall of 1911 and covered all clusters which were found to have hatched and therefore belong to the 1910 brood of moths. This count was more or less inaccurate, as many of the egg clusters were removed from the trees after a year's exposure to the elements. The count indicates, however, that there was a large increase in infestation between 1910 and 1911, and that in 1912 the gross infestation was slightly reduced. A heavy reduction occurred in 1913, while in 1914 a considerable increase was noted but not nearly as great as was the case from 1910 to 1911.

The conclusion which will inevitably be drawn from these figures will not apply to other localities in the infested area. There are many locations where a marked increase was noted in 1913 or where a marked decrease was noted in 1914, but taking the territory as a whole it gives a general idea of the trend of increase or decrease for the period covered.

Knowing the conditions, one can not fail to be impressed with the results that have already become apparent from the introduction of parasites and the work of the wilt disease. Although the season of 1914 was not as favorable to the natural enemies as was the case in 1910, the proportional increase in the number of egg clusters was considerably smaller. Unfavored food plants have, of course, been instrumental in holding down the increase in some of the points, but the amount of infestation in points where unfavored food predominates has remained rather constant, so that it has not been as great a factor in the reduction noted as the other elements just mentioned.

Much careful work has been required to secure this data. For about six months in each year upward of 20 men have been engaged in this work. During the summer a part of the men made observations on the feeding habits of the gipsy moth caterpillars on different food plants in their sections. Observations on the presence of

natural enemies were also made and from time to time collections of egg clusters or caterpillars near the points were obtained and sent to the laboratory in order that the percentage of parasitism might be determined. This work should be continued in order to determine whether after the natural enemies become firmly established the outbreaks of this insect will be periodical over a large territory or whether, as is the case at the present time, the smaller colonies will increase so that stripped areas will be found scattered over the entire region.

DISPERSION WORK.

For the past three or four years considerable attention has been paid to the means by which the gipsy moth spreads. As the female moth does not fly it is apparent that the dispersion of the species must be very slow unless it is carried by other means. Egg clusters may be transported on lumber, forest products, Christmas trees, or other material which is likely to be shipped long distances from the infested area. This matter has been given careful consideration and means have been taken to prevent the spread of the moth in this way. Information concerning methods used are given under the quarantine part of this report.

In the spring of 1910 a number of experiments were conducted which showed that first-stage gipsy-moth caterpillars may be carried by the wind, and the information secured at that time has been published.[1]

Since this work was carried on more elaborate experiments have been conducted by Mr. C. W. Collins and assistants, to obtain long-distance records on the spread in this manner. A study has also been made of the likelihood of the insect being spread by caterpillars drifting in streams, or by wood or other material which is infested with egg clusters floating in rivers and becoming lodged in territory which was not infested. At present wind spread seems to be the chief natural means by which the insect becomes established in new territory. The trend of the spread is toward the north and northeast on account of the fact that the warm prevailing winds before the first of June, when the caterpillars are in the first stage, usually blow in those directions. This has resulted in a large increase in the area infested in Maine, and the territory in that State will probably continue to extend as long as large areas are seriously infested in New Hampshire and Massachusetts. The western spread of the insect has probably been greatly retarded by reason of the fact that low temperature, causing the caterpillars to be inactive, has prevailed when the winds came from the east or northeast. Heretofore serious infestation did not occur in southeastern Massachusetts or Rhode Island; hence winds from the southeast were not an important factor in

[1] Burgess, A. F. The dispersion of the gipsy moth. U. S. Dept. Agr., Bur. Ent., Bul. 119, 62 p., 16 pl., 6 fig., 1 map, Feb. 11, 1913.

causing spread into Connecticut or the area in Massachusetts south of Worcester. Recently, however, the infestation has increased to a great extent in southeastern Massachusetts and Rhode Island, and unless vigorous means are taken to abolish these sources of supply, rapid infestation of eastern Connecticut and territory in Massachusetts lying immediately north of that State will result. In fact, during the past season a large increase has been found in the western tier of towns in Rhode Island and the eastern tier in Connecticut. In eastern Connecticut the white oak, which is one of the most favored food plants of the gipsy moth, is exceedingly common in the woodlands, and the difficulty of controlling the moth under these conditions is very great.

A series of experiments has been conducted to determine how far male moths will be attracted by the females. The purpose is to determine the probability of scattered females being fertilized if they occur at a long distance from a gipsy-moth colony.

SECONDARY INSECT INVESTIGATIONS.

In the fall of 1912 large numbers of oak trees in the areas that had been defoliated by the gipsy moth were found in a dying condition. Examination showed that many of the trees had been attacked by a bark borer, which proved to be *Agrilus bilineatus* Web. The matter was taken up with Dr. A. D. Hopkins, in charge of Forest Insect Investigations of the Bureau of Entomology, and arrangements were made for cooperative study of this insect. Dr. Hopkins was to direct the work, and the salary and expenses of an assistant, Mr. H. A. Preston, who was to give his entire time to the work, were to be paid by this branch. Investigations have been carried on and the life history of the insect worked out. It appears from the information secured that continuous work on this project is not necessary, and the cooperative arrangement was discontinued July 1, 1914. The data relative to the life history and habits, as well as control measures, is in the hands of Dr. Hopkins and will doubtless be published at an early date.

For the information of woodland owners who wish to preserve their oak trees it can be stated that all trees which are in a dying condition in September should be marked so that they can be cut during the winter. The wood should be removed from the lot and if it can be used for fuel the hibernating larvæ will be destroyed. Inasmuch as the oak is very favored as a food plant by the caterpillars of the gipsy moth and as the Agrilus beetles prefer to attack weakened trees, it would seem rather difficult to preserve oak growth unless considerable expense was involved in spraying or treating gipsy-moth egg clusters in order to keep the trees in a vigorous condition. This is impracticable in most woodlands in the infested area. Park or ornamental trees can be handled in this way and the cost is not prohibitive.

RESULTS OF EXPERIMENTAL WORK.

Many of the experimental projects which have been undertaken are nearing completion and detailed reports will be published later.

The information on food plants will now form a definite basis for practical work, and as has been brought out by the observations in Europe on both parasites and food-plant conditions, it will be necessary to bring about in our forests a great reduction of the favored food plants of the gipsy moth before natural enemies can be expected to keep this insect within reasonable bounds.

The parasites and wilt disease, as has already been shown, are doing effective work, but the results would be greatly amplified by eliminating favored food plants.

The study of the increase of the moth in the field furnishes valuable data on all phases of the forest control problem, while the work on dispersion is of special value in connection with the field control work which is being carried on.

Secondary insects are important inasmuch as they may prevent the recovery of many trees which have been defoliated and which would, under normal conditions, gradually recover.

SILVICULTURAL WORK.

During the time the gipsy moth has been known to exist in this country it has done an immense amount of damage to tree growth of the infested region. The injury has caused the death of many of the trees attacked or the retardation of their growth and development, and has produced conditions favorable to the increase of secondary enemies. The tree growth affected may be divided into three classes, (1) fruit trees, (2) shade or ornamental trees, and (3) forest trees. All have suffered severely, but owing to their greater value and relatively smaller numbers it has been possible to prevent a large amount of the injury by applying hand methods of suppression to fruit and shade trees. Gipsy-moth damage to forest trees, however, can not be controlled in the same way owing to the great expense involved, hence the problem of preventing damage in woodlands is a serious one. In some European countries this has been solved to a considerable extent by growing species which are not so susceptible to gipsy-moth attack. The investigations on the food plants and feeding habits of the gipsy moth indicate that the work of eliminating the most susceptible and encouraging the growth of those that are not favored as food by this insect is likely to give good results. As this work involves, to a considerable extent, the practice of silviculture, the Bureau of Entomology requested and received the cooperative assistance of the Forest Service, and these two branches of the Department of Agriculture are now working together on this problem. Mr. George E. Clement, who was formerly an assistant in the Forest

Service, has been appointed to take charge of the investigations along this line. The table given under the "food-plant experiments" indicates in a general way the degree of susceptibility to moth attack of some of our more common forest trees. Certain species, however, are of little commercial value, and it is desired to discourage their growth, as well as those that are particularly susceptible to gipsy-moth attack. In the case of valuable species that are susceptible to attack and for the growth of which a large portion of the infested region is favorable, the only step which can be taken is to determine whether or not they can be sufficiently protected from serious damage by associating with the less susceptible species in small proportions. Of course, the presence of these species may jeopardize the safety of the associated species which would otherwise be immune. However, before abandoning these species careful experiments will be made to determine whether there are associations with which they can join with safety.

The chief fact that reduces the liability of certain species of trees, particularly conifers, to gipsy-moth attack is that the *very young* caterpillars do not feed upon them. Therefore, if there are present no trees or undergrowth upon which the young caterpillars will feed and thereby develop to a size which enables them to attack conifers or similarly susceptible species, they will not be attacked. Thus it appears that certain species can be grown pure or in exclusive association and be free from gipsy-moth attack. Any system of forest management should endeavor to produce in a given area only trees of commercial value, and the foregoing lists (pp. 14–15) indicate the most suitable species for selection.

In converting a given stand of timber into one which shall be immune from gipsy-moth attack, the different classes of trees should be considered for removal in the following order:

(1) Trees of naturally low commercial value and susceptible to gipsy-moth attack.

(2) Trees of low commercial value on account of growing in unfavorable situations and susceptible to gipsy-moth attack.

(3) Trees of commercial value, favorably situated, and subject to gipsy-moth attack.

(4) Trees of naturally low commercial value, but not liable to gipsy-moth attack if properly associated.

(5) Trees of low commercial value on account of growing in unfavorable situations and not liable to gipsy-moth attack.

(6) Trees of commercial value favorably situated and not liable to gipsy-moth attack.

Silvicultural conditions in the woods of the infested region are very poor. Through repeated fires and heavy and inconsiderate cutting, the growth of weed trees has been greatly favored and the growth of

some species has been favored in situations quite unsuited to their requirements. This is particularly true in the case of the oaks and gray birch. These species constitute a very large proportion of the deciduous growth of the region and are very susceptible to gipsy-moth attack. On a great deal of the area now covered by these species the white pine would grow to much better advantage, would yield a much more valuable product, and if pure, or nearly so, would prove immune to gipsy-moth attack. The white pine reproduces itself readily under favorable conditions, and is already fairly abundant in numerous localities. For these reasons the white pine recommends itself very strongly as a substitute for the existing moth-susceptible species, and this species has been considered to a very large extent by this department in its experiments to create a safe stand of timber. The deciduous species which are of value and immune to gipsy-moth attack require most favorable situations for their profitable development, and such situations are very few and of small area. An exception in the case of chestnut may be made in this connection. This is a valuable tree and one well suited to grow over a considerable area. Its growth is not recommended on account of its susceptibility to the widespread and fatal chestnut blight. But, like the red oak, it may be found possible to grow it satisfactorily in small numbers with other species.

EXPERIMENTAL WORK.

The experimental work has been conducted by means of small areas known as "sample plats." These vary in size from one-half an acre to 6 acres and occur both scattered and grouped in different parts of the infested region. They are necessarily located on the lands of private owners who are willing to submit their lands to this use.

An effort has been made to distribute this work as widely as possible over the infested region. (Pl. IX.) In this way the greatest variety of conditions is encountered and the results are available to the greatest number of woodland owners. Each sample plat varies from another in one or more of the following points: Composition of stand, age of stand, degree of infestation, and method of treatment. Each sample plot generally consists of two parts. One of these is the portion upon which actual experimental work is done and the other serves as a control or check plat. Upon the latter nothing whatever is done, as its purpose is to provide a means of comparing results under natural and artificial conditions. The corners and boundaries of all plats have been plainly marked, and the areas surveyed and mapped. All trees 1 inch and over in diameter have been calipered on each plat and control, and the measurements recorded. Forest descriptions of each plat have been written.

Where small white pines have occurred in any quantity they have been counted and the numbers have been recorded by foot-height classes. The best available indication of the degree of gipsy-moth infestation seems to be the number of egg clusters, and for this reason the egg clusters have been counted on each plat. Egg clusters will be counted periodically in the future in order to determine the effect of treatment upon the infestations.

After the foregoing steps have been taken, the growth on each of the managed areas has been thinned. Different silvicultural systems have been used, but in general the object has been to remove the greatest number of susceptible trees consistent with the silvicultural requirements of the trees to be left. In some cases the bulk of the stands consisted of susceptible species, and in these the thinning made was preliminary to a later clear cutting.

After cutting, the number of trees of different diameters and species have been counted and recorded, the amounts of products have been measured and recorded, brush has been piled and burned, careful notes of the changed conditions have been made, and an effort has been made to compute the cost of the work and the value of the products on each plat. In some cases numbers of small naturally produced white pine have been supplemented with planted 2-year-old seedlings from the nursery. In cases where plantings were made the cost of the seedlings and the planting was borne by the owner of the woodland. In addition to the sample plats already mentioned, one 10-acre tract has been selected in each of the following towns in New Hampshire: Peterboro, Franklin, Warner, and New Durham. The growth on all these plats is largely inferior hardwoods which are particularly liable to gipsy-moth attack. The infestation in each case is not heavy. As there is more or less white pine growing among the hardwoods the plan is to cut the latter clean and to replace these trees by planting enough white pine to produce a stand which will be free from gipsy-moth damage. The results of these experiments will not be available for several years, and during this period careful notes on conditions will be made.

MIDDLESEX COUNTY FOREST SURVEY.

In order to get some definite information concerning the distribution of the various kinds of timber stands in the region, a rough forest map of the county of Middlesex in Massachusetts has been made. This work has shown that the forest growth is very uneven and complex, and that there is a wide variation in the composition of stands within relatively small areas. The existing growth of trees on any area indicates very infrequently the growth for which the conditions on the area are best suited. From data secured by this survey and observations made throughout the infested region, the crying silvi-

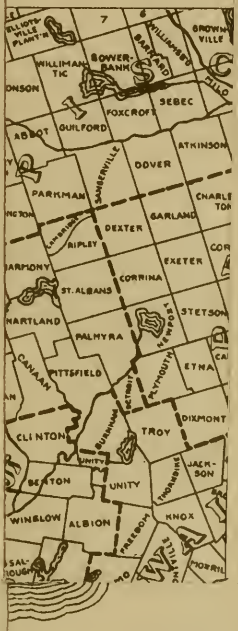
cultural need of the woods is obviously a great reduction of their diversity and the replacement of a large portion of the species by those which have a greater commercial value, and for which the conditions for growth are much better adapted. The steps needed to accomplish this are in many instances precisely those which appear to be necessary in controlling gipsy-moth attack by silvicultural practice.

PROPOSED FOREST EXPERIMENT.

In order to determine the practicability of carrying on an experiment over a large area preliminary surveys have been made of the forest growth in the town of Winchendon, Mass. This work has been attempted in cooperation with the State forester of Massachusetts, Mr. F. W. Rane. The original growth in this town was undoubtedly coniferous, but there has been considerable cutting and as a result hardwood growth of various species has become established. Oak does not predominate, however, in this region and it is hoped that sufficient cooperation can be secured from the woodland owners in the town to handle the forest area so as to bring it into a growth which will not be susceptible to gipsy-moth attack. The preliminary survey has been completed and the data are now being compiled with a view to determining whether a plan of this sort can be worked out on an extensive area.

SCOUTING WORK.

The scouting work consists in examining the territory along the outside border of infestation, and in treating the gipsy-moth colonies adjacent to the border for the purpose of preventing spread of the insects to other parts of the United States. This work is in charge of Mr. L. H. Worthley, who is assisted by Mr. H. L. McIntyre. The territory is divided into six sections with the following men in charge of a section: Mr. D. G. Murphy, Worcester, Mass., H. A. Ames, Athol, Mass., H. N. Bean, Keene, N. H., F. W. Graves, jr., Bradford, N. H., F. W. Foster, Plymouth, N. H., and C. E. Totman, Canaan, N. H. Parties consisting of five trained scouts in charge of a foreman are detailed to make the examinations and treat the infestations, each general foreman having from 5 to 10 crews of scouts under his supervision. In order to check up the thoroughness with which the work is done in the lightly infested territory, a party, usually consisting of two experienced men who are known as special scouts, examines the work after the regular inspection has been made in order to see whether egg clusters of the moth have been missed and that the work was thoroughly done by the scouts. Each scout is required to place a characteristic mark on every tree examined by him so that the responsibility for leaving egg clusters can be readily determined. By following up this plan the force is maintained at a high degree of

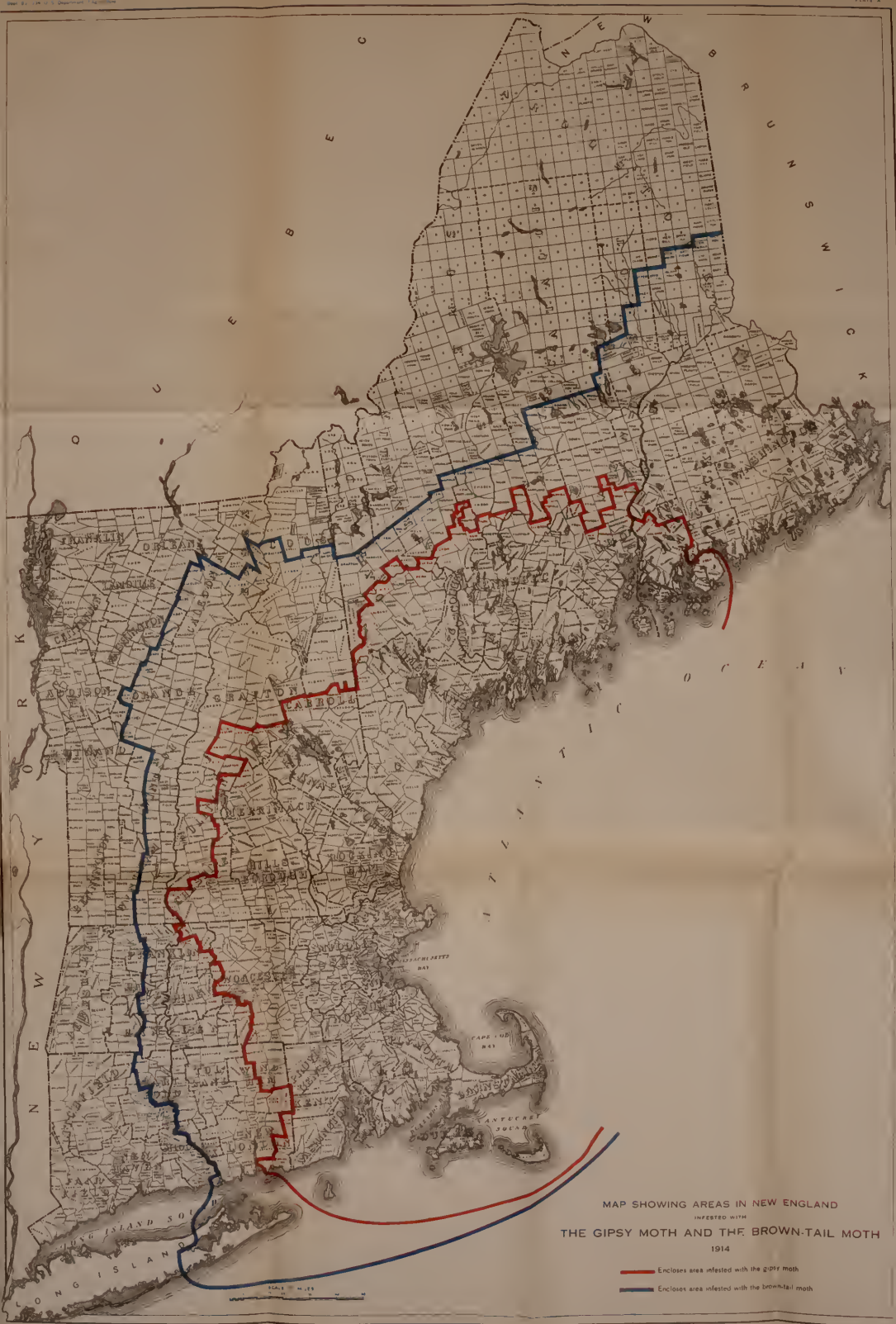


MAP

VICULTURA

MAP SHOWING TOWNS IN NEW ENGLAND
IN WHICH
SILVICULTURAL EXPERIMENTS ARE BEING CONDUCTED
1914

● Towns indicated thus



MAP SHOWING AREAS IN NEW ENGLAND
INFESTED WITH
THE GIPSY MOTH AND THE BROWN-TAIL MOTH
1914

Encloses area infested with the gipsy moth

Encloses area infested with the brown-tail moth

efficiency, the careless and negligent men being dropped from the rolls. When large colonies are found crews of woodchoppers are employed temporarily to cut out the worthless trees and clean up the undergrowth in order to render the area in condition for effective operations.

The accompanying map (Pl. X) shows the territory which was known to be infested by the gipsy moth in the fall of 1913. In organizing the work a large party of scouts was sent to Maine for the purpose of determining whether the infestation had spread beyond this line. The results of the examination show that a large number of towns are infested outside the border previously established. The work was continued until late in December, when it was necessary to transfer the men on account of deep snow and extremely cold weather, the temperature for a number of days being as low as 20° to 25° below zero. In all, 155 towns were scouted in Maine, and of these 81 were found infested. The increase in the number of towns over that of previous years is largely explained by the fact that during the winter of 1912–13 the scouting work was not completed on account of snow and also because of the undoubted dissemination of the moth by means of the spread of the small caterpillars by the wind. The manner of this kind of spread has already been explained in this report. Suffice it to say, the general trend of dispersion of this insect has been toward the north and northeast on account of the fact that the prevailing warm winds during the time the caterpillars are hatching blow from the south and southwesterly directions. The work was continued from January until April in New Hampshire, Massachusetts, Rhode Island, and Connecticut.

On February 3, 1914, a report was received that several gipsy-moth egg clusters had been found on an estate at Bratenahl, Ohio, a suburb of Cleveland. The matter was at once investigated and two experienced scouts were detailed to make an examination of the estate and the surroundings. At the time the work was done there was considerable snow on the ground, making inspection work difficult. Seven new egg clusters were found and treated and later in the season the colony was burlapped and the trees sprayed. The work in Ohio was done in close cooperation with the Ohio Agricultural Commission, and work in the colony since the original scouting was done has been carried on by the assistants of Mr. N. E. Shaw, State nursery and [illegible]hard inspector.

On May 7, 1914, a report was received from Mr. George G. Atwood, [illegible]hief of the division of horticulture of the State of New York, that a [illegible]ipsy-moth colony had been found at North Castle, Westchester [illegible]ounty, N. Y. Inspectors from this office were detailed to treat egg [illegible]lusters, and several experienced scouts were transferred to assist in [illegible]amping out this colony. The principal infestation occurred on a [illegible]rge estate, and the caterpillars began hatching soon after the first

egg clusters were found. A considerable area was scouted around the infestation, and egg clusters or caterpillars were found over an area of about three-fourths of a square mile. Many of the trees were growing on rough and rocky soil, so that it was very difficult to do thorough work. About 15,000 egg clusters were treated during the month of May.

In addition to the scouting work already mentioned, a special examination was made of the entire town of Geneva, N. Y., but no gipsy-moth egg clusters were found. In 1912 a small colony was found in this city. It has been very thoroughly treated by the assistants of the commissioner of agriculture, and it is now believed that the insect has been exterminated. The scouting party detailed for the Geneva work spent one week in examining trees in Seneca Park, Rochester, N. Y., but no traces of the moth could be found.

Special scouting work was carried on in the towns of Lenox, Stockbridge, and Great Barrington, Mass., during the winter. Infestations have previously been found in these towns, but the examination resulted in finding but one egg cluster in Great Barrington, one in Stockbridge, and two in Lenox, indicating that good results have been secured from the treatment which had been applied during the previous season. A careful inspection was also made in the town of Wallingford, Conn., which was found infested some years ago, but no egg clusters were discovered.

The following table shows the number of towns which have been scouted for the gipsy moth and the number of new towns which were found infested during the winter of 1913–14.

TABLE IV.—*Scouting operations for the gipsy moth during the winter of 1913–14.*

State.	Towns scouted.	Newly infested.
Maine	155	81
New Hampshire	73	6
Massachusetts	36	7
Rhode Island	19	17
Connecticut	13	10
New York	3	1
Ohio	1	1

In nine towns in New Hampshire and two in Massachusetts, infested in 1912–13, no infestations could be found the following winter, and recommendations were made that these towns be excluded from the quarantined area. This was approved by the Federal Horticultural Board, and the border towns of the area quarantined for the gipsy moth include only those that have been found infested during the past winter.

The plan of the work has been to examine the territory in Maine chiefly for the purpose of securing data as to where the quarantine line should extend. It is impossible to prevent the spread of the small caterpillars by the wind, and it has therefore been deemed advisable to confine the clearing-up work along the border to the territory in New Hampshire, Massachusetts, Rhode Island, and Connec-

ticut. Accordingly early in the spring arrangements were made to place tanglefoot bands on trees in all the colonies about three towns wide along the border and from the time this work began the greater part of the scouting force was transferred to the work of applying and patrolling these bands.

In the colony in Westchester County, N. Y., 6,000 tanglefoot and 4,000 burlap bands were applied by the inspectors of the State department of agriculture. The State purchased a high-power spraying machine and very thoroughly sprayed the infested area and surroundings. The colony in Ohio was similarly treated by the State officials, and in both cases excellent results have been secured. This office has kept in constant touch with the work in these States and has also had a representative directing the work in the Berkshire Hills infestations in Great Barrington, Stockbridge, and Lenox.

Inasmuch as many of the new infestations were found on apple trees during the winter, a record has been kept of all such trees inspected and of the number of miles of roads scouted by the men. This information is given in the following table:

TABLE V.—*Results of scouting operations for the gipsy moth.*

State.	Towns scouted.	Colonies found.	Egg clusters found.	Apple trees inspected.	Miles of road traveled.	Tanglefoot bands applied.
Maine	155	.....	.....	764,081	4,768	.....
New Hampshire	73	1,656	25,427	1,354,908	4,334	68,336
Massachusetts	36	794	11,987	484,731	2,553	58,315
Rhode Island	19	[1] 309	[1] 207	232,190	987	5,324
Connecticut	13	[1] 157	[1] 124	332,036	884	4,767
Total	296	2,916	37,745	3,167,946	13,526	136,742

[1] In a number of these colonies pupa cases only were found.

The following conditions found in 1913 and in 1914 are of interest. In New Hampshire no egg clusters were found in 198 of the colonies that had been treated during the previous years, and in 641 of the 1,656 colonies found in the winter of 1913 no larvæ were found in the spring of 1914. In Massachusetts no egg clusters were found in 68 of the colonies that were treated during the winter of 1912–13, and in 124 of the 794 colonies located in the fall of 1913 no larvæ were found in the spring of 1914. In Rhode Island 276 of the 309 colonies found and treated in the fall of 1913 failed to produce larvæ in the spring of 1914. In Connecticut 136 of the 157 colonies treated in 1913 failed to produce larvæ the following spring.

During the summer of 1914 woodland scouting was carried on in Thompson, Conn., and Rutland, Mass. The former town is heavily wooded and is reported to contain about 30,000 acres of forest, a considerable part of which is oak growth. As a result of the examination of the woodland in this town 73 gipsy-moth colonies were discovered. All of them were small infestations, indicating that the species is established and is well scattered through the woodland.

GENERAL RESULTS SHOWN BY SCOUTING WORK.

The scouting work for the season has shown very encouraging results. In addition to the large number of towns along the outside border where the infestation has been greatly reduced or where it has been cleaned out during the past year, an excellent showing has been made in a number of badly infested towns in Massachusetts and New Hampshire which are just inside the border. In a large number of these towns which were found severely infested in the winter of 1912–13, a large decrease in the number of egg clusters has been found this year. In the town of Bradford, N. H., where over 3,000 egg clusters were treated during the former year, only 200 were found this season. In Hillsboro the records show a reduction of from 8,000 to 500, although the number of small colonies, many containing a single egg cluster, has increased. In Henniker and Warner, N. H., a large decrease has also been noted and the same is generally true in the border towns where work is being carried on.

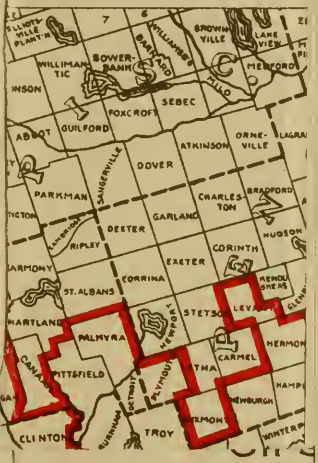
The work on the tanglefoot bands during the entire season gave very gratifying results, and a very large number of the colonies where caterpillars were present early in the season showed no caterpillars or pupæ at the close of the work on tanglefoot bands on August 1. Only a few caterpillars were found in the western part of the area in New Hampshire, Rhode Island, and Connecticut.

No caterpillars were found in Lenox, Stockbridge, or Great Barrington, Mass. About 400 yards from the old infested area in the latter town 43 egg clusters were found in a rock heap during the caterpillar season which, of course, was under the snow when scouting work was done. Some very thorough work was done at this infestation, and only one pupa was found this season. Of course there is danger of some spread from it, and during the coming season some very thorough scouting will be done in this vicinity.

No caterpillars were found at Wallingford, Conn., this season.

In the badly infested woodland colony in Orange, Mass., where some 1,000 egg clusters were located, there were but 1,182 larvæ found during the summer.

The spraying work during the summer gave very satisfactory results, treatment being applied in border towns from Hubbardston, Mass., as far north as Andover, N. H. Many of the localities where spraying was applied were difficult to reach on account of being inaccessible from roads or water supply, but owing to the careful plans made by the foremen the work was not greatly handicapped on this account. In a number of cases the owners of the areas which were infested offered every cooperation possible in facilitating treatment. A few cases have been found, however, where spraying could not be attempted on account of the unwillingness of the owners to have their pasture trees treated because the grass was needed for grazing stock. In instances of this sort the infestations were cared for by creosoting egg clusters and destroying the caterpillars under tanglefoot bands.


BOWER-BANK
WILLIMANTIC
SEBEC
FOXCROFT
GUILFORD
ATKINSON
DOVER
PARKMAN
GARLAND
DEXTER
RIPLEY
CORINTH
EXETER
CORINNA
ST. ALBANS
PALMYRA
CARMEL
TROY
CLINTON
BROWN-VILLE
LAKE VIEW
ORNE-VILLE
CHARLES-TON
BRADFORD
HUDSON

MAP SHOWING
GIPSY MOTH QUARANTINE DISTRICTS
1914

BROWN-TAIL MOTH SCOUTING.

The spread of the brown-tail moth is not easily controlled by artificial means unless the insect can be reduced to minimum numbers. Owing to the large territory over which the insect has spread, it is not possible to carry on extensive scouting or control work by the use of hand-suppressive measures. During the year a considerable area, however, has been examined in Maine, New Hampshire, Vermont, Massachusetts, Connecticut, and New York, and areas have been found infested where the insect was not known previously to exist. The work of the commissioner of agriculture of Vermont and his assistants has been very effective in reducing the infestation in that State. The principal new infestations were found in Connecticut, and a greater part of these were located by the assistants of the State entomologist. Several webs have also been found on Fishers Island and Long Island, N. Y., so that, in all, four towns on these islands are known to be infested. The New York infestations were discovered by the inspectors employed by the State department of agriculture, and several scouts from this office were sent late in the spring to check up the work and cover a part of the area concerned.

QUARANTINE WORK.

The quarantine work is supervised by Mr. D. M. Rogers, who is assisted by Mr. Harry W. Vinton, and the operations are confined to the territory in New England and New York which is infested by the gipsy moth and the brown-tail moth. As a result of the provision of the Federal plant quarantine act, which was passed by Congress August 20, 1912, a domestic quarantine [1] has been declared by the Federal Horticultural Board, covering the territory infested by each of these insects. While the legal authority for declaring quarantine is vested in the board, the cost of administering the work is defrayed by the appropriation for the Bureau of Entomology for "Preventing the spread of moths." The object of this work is to prevent egg clusters or larvæ of the gipsy moth, or winter webs of the brown-tail moth, from being carried out of the infested areas on shipments of trees or forest products. The regulations for enforcing this quarantine provide that all material of this character before being accepted for shipment to points outside the infested district must be inspected and must be accompanied with an official certificate of the Federal Horticultural Board stating that an examination has been made and that the material is free from infestation. Shipment of Christmas trees and similar material to points outside the quarantined area is prohibited. In order to facilitate the work, the infested territory has been divided into 22 sections and a competent inspector has been placed in charge of

[1] For details, see Notice of Quarantine No. 17, of the Federal Horticultural Board, effective Aug. 1, 1914.

each. (Pl. XI.) It is the duty of each inspector carefully to examine all lumber or forest products, cordwood, telephone poles, railroad ties, tan bark, etc., which may be shipped from any points in his district to points outside the infested area after the proper application has been made and to issue certificates of inspection if no infestation is found. In accordance with the provisions of the quarantine regulations, transportation companies are required to reject shipments which are not accompanied with proper certificates. During the season when nursery stock is being moved, examinations are made of all woody plants which are consigned to points outside the quarantined area. A number of special inspectors are employed for this purpose in addition to the men engaged on the regular lumber-inspection work. In order that this work may be of the most thorough character so as to safeguard purchasers in other parts of the United States, a tree-by-tree inspection is made of all trees and plants growing in the nurseries before they are dug for shipment. Another inspection of the plants is made at the time they are being packed for shipment. During the fiscal year 1914, 17,076 shipments have been examined and 4,476 specimens of the gipsy moth and 1,435 specimens of the brown-tail moth in their various stages have been found and the insects destroyed. This has resulted in preventing these pests from spreading to many localities not now infested. The destinations of these shipments ranged as far south as Jacksonville, Fla., as far west as Prineville, Oreg., and as far north as Montreal, Quebec.

The destination of shipments on which infestations were found and destroyed are given below:

State.	Number of shipments.	State.	Number of shipments.	State.	Number of shipments.
Colorado	1	Maine	12	Pennsylvania	10
Connecticut	25	Michigan	4	South Carolina	1
District of Columbia	1	Missouri	5	Vermont	35
Florida	3	New Hampshire	7	Virginia	2
Georgia	1	New Jersey	11	Canada	6
Illinois	14	New York	34	England	1
Iowa	1	North Carolina	1		214
Maryland	2	Ohio	12		
Massachusetts	24	Oregon	1		

BROWN-TAIL MOTH QUARANTINE.

The enforcement of the brown-tail moth quarantine is conducted in connection with the inspections carried on to determine whether shipments are infested with the gipsy moth. It is not necessary, however, to inspect lumber for this purpose. Deciduous nursery stock is examined and all webs of the moth destroyed before shipments are permitted. In order to prevent as far as possible the carriage of the adult female moths on trains, inspectors have been placed at several main railroad junctions along the border of infestations to examine the trains during the time the moths are flying. These insects are strongly attracted to bright light and the results which have been

secured from these inspections have been very satisfactory. The inspection work in 1914 began on July 6 and was continued until July 31.

The stations where trains were examined and the number of adults found are given below:

Station.	Brown-tail moths found.	Station.	Brown-tail moths found.
Bellows Falls, Vt	16	North Stratford, N. H	0
Greenfield, Mass	9	Springfield, Mass	1
Gorham, N. H	6	St. Johnsbury, Vt	457
Hartford, Conn	0	Wells River, Vt	247
New London, Conn	7	White River Junction, Vt	1,484

In addition to the foregoing, 296 adults were found and destroyed at arc lights in White River Junction, Vt.

RESULTS OF QUARANTINE WORK.

The results of the quarantine work have been very satisfactory. Only one infested shipment of plant products has been known to pass out of the territory and it was promptly returned.

Several carloads of stone and quarry products have recently been found infested with gipsy-moth egg masses and a quarantine was declared by the Secretary of Agriculture on October 23, 1914. Such products must now be inspected and certified the same as plant products.

Considering the number of infested shipments that have been found and the wide range of country to which they would have been sent if the egg clusters had not been found and treated, it is safe to assert that this work has resulted in enormous saving of money value to the agricultural and forest interests of the United States.

COOPERATIVE WORK.

Since the Federal work was commenced, active cooperation has been secured from the States in which operations were being carried on. While the organization of the State force and that of the Government force are entirely distinct the work is planned in such a way as to avoid duplication and to secure the best results. The general plan is for the Bureau of Entomology to concentrate its efforts in stamping out colonies in the territory along the western border of infestation from Lake Winnipesaukee to Long Island Sound, and to carry on as much work as may be necessary in eliminating the isolated colonies that have been found in New York, Ohio, western Massachusetts, and Connecticut. The State officials concentrate their efforts in the territory inside the border towns. Owing to the hearty spirit of cooperation that has existed between the Bureau of Entomology and the officials in New York, Ohio, and Connecticut, where isolated colonies are present, it has not been necessary for this office to expend much money for control work, as the States concerned have made every effort to stamp out these colonies. A system of following up and

checking over the work done by these States has been adopted, so that very satisfactory work has resulted. In the distribution of natural enemies arrangements have been made to cooperate with the State officials, and this has resulted in the establishment of more colonies of parasites than would otherwise have been possible. An arrangement has been made with the Massachusetts State Board of Agriculture so that speakers will be furnished to discuss the gipsy-moth problem at farmers' institutes.

In the spring of 1914 a colored poster was prepared showing the life histories of the gipsy moth and the brown-tail moth and several of the introduced natural enemies. These posters have been distributed to all the post offices in the infested district, to granges, libraries, and educational institutions. Reproductions from this poster have been made in the form of post cards and distributed to schools and parties interested in the work.

During October, 1914, an exhibit covering the gipsy-moth work of the bureau was made at the Boston Pure Food and Domestic Science Exposition, as a part of the Government exhibit. Living parasites were on exhibition as well as mounted specimens and other information.

Efforts are continually being made to advise property owners concerning the methods which should be taken by them to prevent serious damage to their trees, and good results are being accomplished along these lines.

CONCLUSION.

The gipsy-moth work of the Bureau of Entomology is well organized and each section is accomplishing good results.

The scouting work and the quarantine work are doing efficient service and preventing the spread of the gipsy moth, but on account of the enormous area which is infested it is impossible to cover much of the woodland. This has resulted in a gradual spread of the insect. It has been possible to restrict this spread very materially toward the westward.

The work of natural enemies, including the parasites, predacious enemies, and disease, have helped materially in decreasing the amount of infestation, and it seems probable that these influences will become more potent factors in the future.

The importance of bringing forest lands into a growth which is unfavorable to the development of the gipsy moth can not be too strongly urged, as the work of natural enemies is likely to fluctuate from year to year on account of adverse conditions or the decimation of the beneficial species by other parasitic forms. Every movement toward bringing about more unfavorable forest growth is therefore a step in solving the gipsy-moth problem.

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DIV. INSECTS.

BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 221

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
June 16, 1915.

(PROFESSIONAL PAPER.)

THE SOUTHERN CORN LEAF-BEETLE.[1]

By E. O. G. Kelly,
Entomological Assistant, Cereal and Forage Insect Investigations.

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INTRODUCTION.

The southern corn leaf-beetle (*Myochrous denticollis* Say) has become a pest of considerable importance during the last few years and has commanded the attention of entomologists on several occasions. Although the habits of this beetle are not fully known, it seems advisable to publish the known facts and suggest possible remedies.

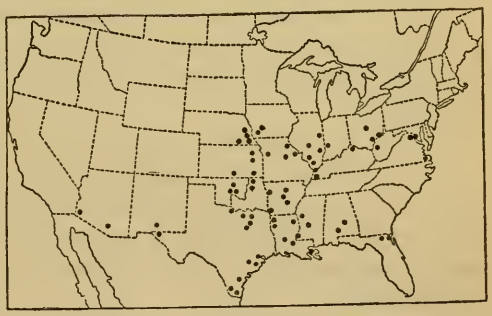

FIG. 1.—Map showing distribution of the southern corn leaf-beetle (*Myochrous denticollis*) in the United States. (Original.)

The writer's attention was first called to the destructive habits of these beetles in the summer of 1905, while investigating insects injurious to corn in southern Illinois. At that time numbers of adults were found feeding on grains of roasting ears in cornfields in the bottom lands of the Ohio River. Since being located by the Bureau of Entomology in southern Kansas the writer has watched this little beetle and as occasion offered made close investigation of its habits and life history. The occurrence of

[1] *Myochrous denticollis* Say; order Coleoptera, family Chrysomelidæ.

NOTE.—This bulletin is of especial interest to entomologists in the southern half of the United States.

numbers of beetles near Wellington, Kans., in 1910, and again in 1913, together with an outbreak in northern Texas in the spring of 1910, and in eastern Arkansas in 1913 and 1914, afforded material and opportunity for further extensive investigations.

Numbers of the larvæ have from time to time been found in the soil, always in close proximity to corn roots which were more or less eaten, but in no instance have they actually been observed feeding on corn roots, although especial attention has been given their feeding habits.

HISTORY.

In the Report of the Commissioner of Agriculture for 1887, Prof. F. M. Webster (Webster, 1887), then a special agent of the Division of Entomology, stated that beetles were observed in Louisiana during April in considerable numbers in fields of young corn. They were found in soil about the stems and attacking the young corn plants by gnawing the outside of the stems, without doing serious injury. His report on a later outbreak at Cheshire, Ohio, in 1900, was the first record of their having done serious damage (Webster, 1900). Since that time, however, they have been reported as having done serious injury at several points in Kansas, notably in the vicinity of Douglas, in 1905, as reported by E. S. Tucker (Tucker, 1905). The writer observed that they did considerable damage to young corn at Wellington, Kans., in 1910 and 1913, and severe damage in the neighborhood of Paris, Ark., in 1913, where several hundred acres of young corn were destroyed in early May, necessitating replanting—the second planting also suffering severely. Again, in 1914, serious damage was done in western Arkansas, but none was recorded in Kansas.

Mr. T. D. Urbahns reported slight injury to young corn in the vicinity of Plano, Tex., in April, 1909. The adults were cutting the edges of young corn leaves, leaving them quite ragged. The infested field was one which had been planted to cotton the previous year and was of the same type of soil as a heavy timbered stretch of black land adjacent.

Mr. Vernon King reported that the beetles had ruined several acres of young corn on farms near Charleston, Mo., in May, 1913, stating that the beetles were more numerous on black soil; in fact, none at all was found on light sandy soil. From one to four adults were observed on each plant and the plants were literally reduced to fragments. (See Pl. I, figs. 1 and 2.) The infested fields were those of recent clearing in bottom lands.

During April and early May, 1915, a second serious invasion of this species took place in this same locality. Mr. King having resigned, the second investigation was carried out by Mr. E. H. Gibson, who used the poisoned-bran bait with good success in destroying

the beetles, applying it about the hills of corn where the beetles were at work.

Observations in both Louisiana and Ohio by Prof. Webster (Webster, 1901) and in Kansas, Texas, and Arkansas by the writer seem to indicate that the insect occurs in destructive abundance on lands that have previously been devoted to pasture or lands that have been allowed to lapse into a semiwild condition, not having been cultivated for several years.

DISTRIBUTION.

The species is widely distributed over the southern half of the United States, extending from the extreme southeastern part of Arizona to southern Texas, becoming more numerous directly north of Brownsville, thence northward to southern Iowa, and eastward to northern Illinois and central Ohio and to Washington, D. C., the most southeastern point recorded being in northern Florida. This insect has not been reported from Tennessee, North Carolina, South Carolina, or Georgia, but evidently it may occur in these States. (See map, fig. 1.)

Prof. F. M. Webster (Webster, 1901) remarks in regard to the distribution of other species—

> *Myochrous squamosus* ranges from northern Arizona and New Mexico to the Platte River in Nebraska and northwest into Montana, probably through western South Dakota and Wyoming. *Myochrous longulus*, the only remaining species to be mentioned, is known to range from southern California and Arizona northward into Colorado, where it has been reported to Dr. Le Conte, without exact locality. It not unlikely occurs also in Utah, although it has not yet been reported from there in the literature, so far as I am able to learn, but in any case overlapping the territory inhabited by *Myochrous squamosus* in northern Arizona and New Mexico, and also probably in Colorado, while the latter species borders on and possibly mingles with *Myochrous denticollis* in southwestern Arizona, eastern New Mexico, western Kansas, and extreme southeastern Nebraska.

DESCRIPTION AND LIFE-HISTORY NOTES.

The insect was described by Dr. Thomas Say in 1824 (Say, 1824) under the name of *Colaspis denticollis*, from specimens collected in Missouri. Dr. Say did not mention any food plant in connection with his description. It was first described as an insect pest to growing corn by Prof. F. M. Webster (Webster, 1901).

THE EGG.

The egg (fig. 2) is small, oval, pale yellow, and about 0.036 of an inch in length and 0.015 of an inch in diameter. The surface is smooth and slightly glistening. The female deposits her eggs in clusters of from 10 to 50 in the field, carefully placing them in small pieces of weeds, hollow straws, in crevices, in clods of dirt, but always near corn plants.

Close searching in the neighborhood of plants other than corn has failed to reveal them, although the beetles have been noted feeding

on other plants at egg-laying time. In the laboratory, under artificial conditions, the eggs will hatch in from 6 to 10 days, rarely going as long as 15 days. Eggs have been observed from early April in northern Texas till the middle of May in Kansas.

THE LARVA.

The newly-hatched larvæ are nearly cylindrical, about 1 mm. long and 0.03 mm. in diameter, tapering slightly and becoming somewhat flattened toward the posterior extremity. They are pale yellow, except the first thoracic segment and head, which are creamy white. The head is a little broader than the thorax, and the body is covered with downy hairs. Within five days after the hatching the larvæ become a creamy white, which color is retained until maturity.

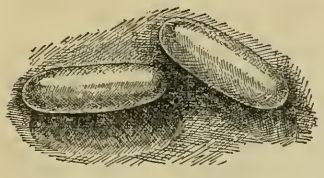

FIG. 2.—The southern corn leaf-beetle: Eggs. (Original.)

The mature larvæ (fig. 3) are 6 to 8 mm. in length and about 2 mm. in diameter. The head is slightly smaller than the thorax, the body becoming a little larger toward the anal extremity. The thoracic segments bear stout legs, and beginning with the second abdominal segment the next seven segments each bear a pair of ambulatory processes (fig. 3, *a*) which terminate in a long hair, accompanied by four shorter hairs. The anal plate (fig. 3, *b*) consists of five parts, which are very characteristic of this species and form a character which separates it from all other larvæ of the Eumolpini group.

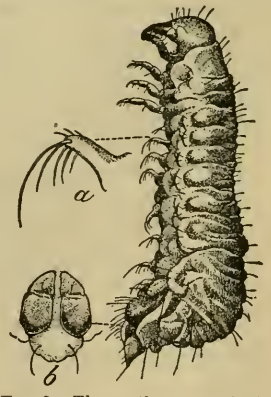

FIG. 3.—The southern corn leaf-beetle: Larva. *a*, Ambulatory process; *b*, anal plate. (Original.)

During the last six years the writer and other members of the Bureau of Entomology have been making efforts to rear the larvæ of this species from egg to maturity, in order to determine definitely its food plant and exact life history. In the laboratory almost every form of receptacle has been used that could be devised, from a tiny vial with several kinds of food in it, fitted with blotting paper to absorb undue moisture, to flowerpots buried in the soil, which it was thought might simulate more natural conditions.

The list of growing plants involved in these experiments is as follows: Cocklebur (*Xanthium spinosum*), smartweed (*Persicaria hydropiper*), Japan clover (*Lespedeza striata*), crab grass (*Syntherisma sanguinale*), sorghum (*Sorghum vulgare*), alfalfa (*Medicago sativa*), cotton (*Gossypium* sp.), corn (*Zea mays*), wheat (*Triticum vulgare*), bluegrass (*Poa pratensis*), pigweed (*Chenopodium* sp.), and barnyard grass (*Echino-*

chloa crus-galli). Kernels of wheat and corn which had been soaked in water, pieces of decaying straws, corn pith, and toadstools were also tried, with negative results.

A few larvæ, fed on a combination of decaying corn pith and growing cornroots, failed to mature, probably for other reasons than lack of proper food, but were sufficiently large for use in identifying those collected in the field.

Numerous searches have been made in cornfields, wheat fields, grass, and fields grown up with weeds, and the larvæ have not yet been found feeding on plants other than corn. Larvæ have been found in the soil in cornfields where cocklebur and corn plants were growing together, and where corn was growing alone, but in no other situation.

The first larvæ found in the field were observed by Mr. T. H. Parks and the writer at Wellington, Kans., on July 20, 1910, in small round earthen cells from 4 to 6 inches deep, with a tiny burrow leading toward the cornroots, which had been more or less eaten. The larvæ hastily retreated to safety and feigned death when disturbed. By way of further determining this habit, a larva was allowed to crawl on the surface of the soil, when on suddenly jarring the soil several inches from it it hastily retreated and "folded up." Although a diligent search was made for feeding larvæ during the following days of July and up until the middle of August, none was found, though numbers of larvæ were unearthed.

The field in which the larvæ were first found is the dark waxy second bottom land which becomes very gummy and sticky during wet weather and very hard during dry weather. The outbreaks and damage reported by Prof. Webster, Mr. Tucker, and Mr. King and those observed by the writer in Kansas, Texas, and Arkansas have all been on soil of this character. In sandy or light soils very few larvæ or pupæ have been found and correspondingly few injured cornroots have been observed.

From the laboratory notes made at Brownsville, Tex., latitude 26°, by Mr. R. A. Vickery, it appears that the larval period probably extends from about April 1 to about June 15, while the writer's observations at Plano, Tex., latitude 33°, and at Paris, Ark., latitude 35°, show that the larval period ranges from April 15 to July 1, and at Wellington, Kans., latitude 37°, from May 1 to July 15.

In the bottom lands of the Arkansas River, near Paris, Ark., the larvæ had pupated and practically all the adults had issued by July 22, 1914, indicating that they began pupating as early as July 1. In the vicinity of Wellington, Kans., the larvæ began to pupate about the middle of July, pupæ being found as early as July 20 and as late as August 14. The period for maturing the pupa seems to be about 15 days, although no exact data have been obtained.

THE PUPA.

The first pupæ (fig. 4) to be found were in earthen cells in the soil near corn plants at depths of from 4 to 6 inches. The finding of pupæ which were nearly mature at this time, some of which changed to adults by the next morning, indicated that the larvæ had finished feeding and were in their pupal cells.

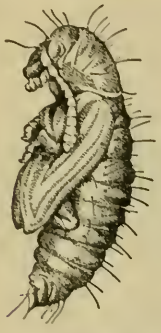

FIG. 4.—The southern corn leaf-beetle: Pupa. (Original.)

The pupa is white until within one day of maturity, when it begins to darken.

In dorsal view the head is bent ventrad; the bristles on the head are prominent and irregularly placed in a double row on the median dorsal line; there is a single row of setæ above the plural suture; the eighth abdominal segment has a semicircular row of setæ and the anal segment is supplied with a stout, curved spine; each abdominal segment bears several stout setæ on the dorsum. In lateral view the body is longer than wide, tapering from the fifth abdominal segment; the antennæ are directed dorsad around the femora of the two front pairs of legs, thence backward with the tips lying near the claws of the middle legs and on top of them; the elytra and wings are rather short, thick, tapering toward the tip, and folded over the posterior legs, the tarsi of which reach the eighth segment. In ventral view the head is as long as the thorax, directed forward, with the front lying between the tarsi of the front pair of legs; the elytra and the tarsi nearly meet ventrally, forming a deep ventral groove. The pupa is 5 to 6 mm. long and from 3 to 3.5 mm. wide.

THE ADULT.

FIG. 5.—The southern corn leaf-beetle: Adult. (Original.)

To the average farmer the beetles (fig. 5) can be recognized as small, dark brownish beetles, more or less covered with bits of soil. They are about three-sixteenths of an inch long and about one-third as wide. They have the habit of dropping from their food plant to the ground and hiding when disturbed, and owing to this habit they are very rarely seen. Quite often farmers have noticed seriously damaged young corn, the plants being literally in fragments, and have been unable to locate the cause on account of this habit of the beetles of dropping to the ground and hiding. It is sometimes difficult even for trained entomologists to locate them.

Dr. Thomas Say (Say, 1824) described the adult as follows:

Body black, slightly bronzed, covered with dense, robust cinereous hairs; antennæ dull rufous at base; thorax with three equal, equidistant teeth on the lateral edge; elytra, lateral edge minutely dentated; tip simple; anterior tibiæ and posterior thighs one-toothed. Length, nearly one-fifth of an inch.

The beetle seems to prefer to feed early in the morning, late in the evening, or at night, or on cloudy days; very rarely it feeds during the heat of the day, and at this time of the day it is generally found under clods of dirt or down beneath the leaves of the plants.

HIBERNATION.

The adult beetles issue from pupal cells about the middle of July in central Arkansas and the 1st of August in southern Kansas, emergence extending over a period of about one month. They do considerable feeding on the kernels of unripe ears of corn and buds of cocklebur before entering hibernation, which begins early in the fall. They have been observed by Mr. W. R. McConnell hibernating under piles of corn husks, in fodder shocks, in cornfields, and also in clumps of *Andropogon scoparius*, *Andropogon virginicus*, and *Cyperus rotundus*. Mr. A. H. Rosenfeld (Rosenfeld, 1911) found one adult hibernating in Spanish moss (*Tillandsia usneoides*).

Adults were found in hibernation in the fall of 1913 throughout bottom-land cornfields near Paris, Ark., these being the same fields that had been devastated the previous spring. In a large cotton field adjacent to one of these cornfields beetles were found in large numbers under piles of rubbish, in the open unpicked cotton bolls, and a large number were found lying on the ground beneath a large pile of recently picked cotton.

While investigating the hibernation of this insect in central Arkansas the writer's attention was called to a cotton gin from the dirt spout of which the beetles were being shaken from cotton which was then being brought in from the fields for ginning. A double handful of living beetles were thus collected in a short time. The manager of the cotton gin informed the writer that he had been noticing these beetles since early fall and that they were more numerous in late November. This cotton gin was located in the Arkansas River bottoms and only such cotton as was grown in the immediate vicinity was ginned.

After leaving this locality, the writer visited a gin located near the edge of the foothills, where both hill-land cotton and bottom-land cotton were being ginned. The bottom-land cotton produced a few beetles, but the upland cotton was apparently free from them. In the town of Paris, two large cotton gins were visited and searched for this beetle, but owing to the fact that most of the cotton they were receiving at this time was from the hill land, none of the beetles could

be found. However, in the pile of rubbish and dirt at the side of the gin which had been thrown from the dirt auger several fragments of dead beetles were found. The manager of this gin could not give any information regarding the occurrence of the beetles. He had noticed, however, some large brown cases which occurred rather numerously early in the fall, probably the pupal cases of the cotton leaf-worm (*Alabama argillacea* Hübn.).

CROPS DAMAGED.

Corn is the only cultivated crop that has been known to be attacked in sufficient numbers to cause serious damage. The beetles, upon first emerging from hibernation in the early spring, attack very young cocklebur and early volunteer corn, the crop not having been planted at that time.

FIG. 6.—Young corn plant showing work of adult of the southern corn leaf-beetle. (Original.)

Besides corn, the beetles have been observed by the writer to attack the young leaves and growing shoots of cocklebur, smartweed, Japan clover, and crab grass. Mr. Vickery has observed them feeding on sorghum and alfalfa—on the latter plant, however, only in rearing cages in the laboratory. Mr. W. R. McConnell has found them feeding on sorghum in the field and also on *Alopecurus geniculatus*. Some of the agents of the branch of Southern Field Crop Insect Investigations have observed them feeding on the cotton plant.

The ragged appearance of the corn plant (fig. 6) is indicative of their presence, especially the notched edges of the leaves, and where the beetles appear in sufficient numbers to devastate a field these notches become so numerous that the plant dies. (Pl. II.) The early planting seems to be the one most seriously affected, although the second planting on the farm of a Mr. Baskins and on other farms near Paris, Ark., was about 50 per cent damaged in 1913, the

FIG. 1.—CORNFIELD DEVASTATED BY ADULTS OF THE SOUTHERN CORN LEAF-BEETLE. (FROM WEBSTER.)

FIG. 2.—CORNER OF SAME FIELD AFTER SECOND PLANTING. (FROM WEBSTER.)

WORK OF THE SOUTHERN CORN LEAF-BEETLE (MYOCHROUS DENTICOLLIS).

FIG. 1.—YOUNG CORN PLANTS KILLED BY ADULTS OF THE SOUTHERN CORN LEAF-BEETLE. (ORIGINAL.)

FIG. 2.—CORN PLANT COMPLETELY DESTROYED BY THE SOUTHERN CORN LEAF-BEETLE. (ORIGINAL.)

WORK OF THE SOUTHERN CORN LEAF-BEETLE.

first planting having been entirely destroyed. The devastation of 1914 was very severe but not so heavy as in 1913.

Considerable search on cotton and wheat growing in the vicinity of infested cornfields near Paris, Ark., developed no damage to these crops.

DISSEMINATION.

The beetles have powerful wings and have been observed in fields long distances from where they originated. Especially was this true in one instance, during the fall of 1910, where it was positively known that they developed in certain bottom-land fields, later migrating 2 miles to a field of late upland corn, where great numbers of them were found feeding upon the belated ears. In this last-mentioned field the farmer planted wheat and in the operation the drill raked up piles of the corn leaves, among which great numbers of the beetles hibernated during the following winter. Counts made the following spring, before they left hibernating quarters, indicated that about 80 per cent of these beetles survived the winter. A lot of the dead beetles were kept for parasites, but no parasites developed. From these hibernating quarters beetles emerged in this same field in late March, after the weather had become warm. They were noticed flying in a northerly direction, though just where they went could not be determined.

It does not seem to the writer that an outbreak of this insect is brought about by the growing of any particular crop on a certain field, but it would appear that an outbreak is very likely to follow where a field has been allowed to lie idle, especially so if allowed to grow cocklebur and volunteer corn for a year or more and to become very weedy and foul, thus affording hibernating quarters.

The fact that adults have been found hibernating in grasslands, in which situation larvæ have never been found, indicates that they do not necessarily hibernate in the field in which they breed, and furthermore that they do fly away from their breeding grounds.

REMEDIES.

A great number of beetles have been taken at lights, which would indicate that a powerful light trap situated in the vicinity of the infested field might materially reduce them. In the early fall, when they are flying in search of hibernating quarters, it is possible that the light trap would catch large numbers.

Judging from the conditions of fields in which they have been observed hibernating in large numbers, the cleaning up of all rubbish in the cornfields early in the fall, especially in fields for very late corn, would prove an effective remedy as a protection for the succeeding crop. The fact that large numbers were observed in the vicinity of cotton gins would suggest that the managers of cotton gins might use

their rubbish and trash for boiler fuel and thus destroy a great number of the beetles.

Ordinarily the beetles attack a field of corn when it is very young and destroy it before the farmer becomes aware of their presence. No remedy has been found that can be recommended in combating them after they enter the cornfield. If the crop is so badly damaged as to be worthless it can be replanted with safety from damage by this insect about one month after the regular planting time. Within a few days after they have killed out the first planting they will leave the field, thus making it safe to replant.

From all the writer has been able to observe or learn the beetles leave their hibernating quarters in early spring, depositing their eggs about young corn plants as soon as these are available for their purpose. It would also appear that the season of oviposition is prolonged and that it is these overwintering beetles that feed upon and destroy the corn plants while thus engaged. This would lead to the somewhat anomalous assumption that the parent beetle under stress of hunger destroys the food plant of the larvæ, which if true would account for the very erratic occurrence of the outbreaks of this pest.

As an additional suggestion, the fact that the beetles appear and disappear with considerable regularity from south to north, taken together with the fact that corn planted three or four weeks after the usual planting season has escaped attack of the beetle, would indicate that something might be gained by delaying corn planting in localities where beetles have been injurious the previous year.

Mr. E. H. Gibson, in his experimental work with this species in the vicinity of Charleston, Mo., during late April and early May, 1915, reports having found that, after repeated trials under varying conditions, carried out with check experiments, the beetles can be readily destroyed by a poisoned-bran bait, consisting of 25 pounds of wheat bran, 1 pound of Paris green, 1 gallon of low-grade molasses, and the juices of 3 oranges, with enough water to bring the mixture to a stiff dough. The best success in the use of this poisoned bait was obtained when applied in the late afternoon. It would seem that this measure might be an extremely practical one if applied to the restricted areas from which the beetles frequently spread, the bait being scattered lightly on the ground among the plants where the beetles are at work.

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No. 226

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
May 27, 1915.

PROFESSIONAL PAPER.

THE VERBENA BUD MOTH.

By D. E. Fink,

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(In cooperation with the Virginia Truck Experiment Station, Norfolk, Va.)

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INTRODUCTION AND HISTORY.

During the fall of 1913 a bed of ornamental snapdragon (Antirrhinum) at the Virginia truck experiment station, Norfolk, Va., was found to be infested by the larvæ of a bud moth. The adults were reared and identified as *Olethreutes hebesana* Walk., or the verbena bud moth. Although long ago recognized as injurious to certain ornamentals, it appears that no attempt had been made to determine its life history, with the exception of a short note regarding the habits of the larva and a description of the different stages. Since 1868, at which date it was fully described, an interval of over 46 years has elapsed and but little has been published concerning it.

The first intimation we have of this insect as a pest occurs in a letter by A. S. Fuller, forwarded in 1868 with specimens to C. V. Riley, then State entomologist of Missouri. Riley reared the adults from the seeds of Tigridia and later identified the moth as an undescribed species belonging to the tortricid genus Penthina. In honor of the discoverer Riley named the species *fullerea*. At about the same time two other workers independently discovered the same insect doing injury to flowering plants. Mrs. Mary Treat found it exceedingly

[1] This term is used in its broadest sense and includes all vegetables, and in addition ornamental plants.—F. H. C.

Note.—This bulletin gives the life history of the verbena bud moth, its food plants, and methods for its control.

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injurious to verbena and sent specimens to Riley for identification, while Miss M. E. Murtfeldt found the insect injuring Antirrhinum at Kirkwood, Mo.

The species was later observed and collected by entomologists in various sections of the country, and notices to that effect appear scattered through our literature.

NAME AND SYNONYMY.

Popularly this moth has only one name, the "verbena bud moth," given it by Mrs. Mary Treat in 1869 from the plant upon which it was found feeding. Scientifically, however, it has in its brief history been known by several names and has been shifted from one genus to another. Both Fernald and Walsingham have listed the species under the genus Penthina. Later it has been listed by H. G. Dyar and J. B. Smith under the genus Olethreutes. As it now stands we have the following synonymy:

Olethreutes hebesana Walk., Dyar, 1902.
Sciaphila hebesana Walk., 1863.
Carpocapsa inexpertana Walk., 1863.
Sericoris fœdana Clem., 1865.
Penthina fullerea Riley, 1868.
Penthina hebesana Wlsm., 1879.

DISTRIBUTION.

Apparently the verbena bud moth is distributed locally at least through the eastern part of the United States. It is evidently a native American species and has been collected and found injurious in Maine, Massachusetts, New York, New Jersey, Pennsylvania, Virginia, Texas, Kansas, Indiana, and California, and is also reported from Canada.

FOOD PLANTS.

So far as known this species has confined its injuries solely to flowering plants. It has been reared from and found injurious on the following food plants: Tiger flower (*Tigridia pavonia*), snapdragon (*Antirrhinum* spp.), flag (*Iris* spp.), hedge nettle (*Stachys palustris*), mullein (*Verbascum thapsus*), verbena (*Verbena* spp.), closed gentian (*Gentiana andrewsii*), false foxglove (*Dasystoma flava*).

According to the records in the Bureau of Entomology it has several times been reared from the stems of *Tigridia pavonia* and was injurious to verbenas on the Department of Agriculture grounds in Washington, where it fed upon the flower heads, webbing a number of seed capsules together to feed upon the young and undeveloped seeds. The heads of verbena are probably not its natural habitat, since it is necessary to web them together. Among other food plants in the records of the Bureau of Entomology are the closed gentian (*Gentiana andrewsii*) and false foxglove (*Dasystoma flava*). It has been found to feed in the dry seed pods of both these species, which may be included among its wild food plants.

THE MOTH.

Mr. C. H. Popenoe found the pods of mullein literally peppered by the work of this insect in Kansas and Indiana and suggests that mullein was probably the original food plant.

DESCRIPTION.

The adult of *Olethreutes hebesana* is a small dark-brown moth (Pl. I, *b*) of the usual tortricid type, with a wing expanse of about one-half inch. A technical description, including the markings, from specimens before the writer, follows:

Alar expanse, 0.50 inch; length, 0.23 inch. Head with buff-brown tufts; eyes and palpi at apices somewhat darker, antennæ short (one-third length of forewing), filiform and simple in both sexes. Thorax with the shoulder pieces and dorsal tuft uniform buff-brown. Abdomen more gray. Forewings silvery gray, with metallic blue reflections more or less intense; the lighter parts carneous, with a silvery luster; and the whole intricately shaded with dark vandyke brown. The light is mostly reflected from the beautifully marked edges of the scales, which are transversely imbricated. There are three principal dark-brown marks, namely, one broad and irregular, crossing the wing a little beyond the middle and containing a more or less complete pale ring on the posterior border just within the anterior median cell; another, subobsolete, opposite, on its inner border. Between this transverse band and the base is a smaller, irregular, brown mark, not extending to the inner margin, and between the pale ring above described and the apex of the wing a third conspicuous brown mark, not extending more than one-third the width of the wing. Each of these dark marks is relieved by a pale border, and between them the brown, blue, and flesh color are intricately mixed. Apex of wing rounded; posterior border dark, with a series of eight or nine more or less distinct rust-brown angular spots, just inside, the two largest being costal; fringes dark brown, with a deep-blue gloss. Hind wings light brown, this color becoming deeper around the posterior margin; fringes lighter. Whole undersurface of a uniform leaden brown, that of forewings somewhat darkest and showing costal marks. No sexual difference is noted except in the narrower and less pointed male abdomen.

Following are the original descriptions of the larva and pupa, from the writings of Dr. C. V. Riley:

THE LARVA.

Penthina Fullerea.—Average length exactly half an inch; general color of a uniform dirty carneous, frequently inclining to yellow and to green; two wrinkles on each segment; head jet-black, without a spot or shade; cervical shield also black, and occupying the whole surface of segment one; piliferous spots in the normal position, but scarcely observable, even with a lens, other than by the hairs proceeding from them; feet, legs, and venter of the same color as upper surface. (Fig. 1.)

THE PUPA.

The chrysalis (Pl. I, *e*).—Average length, 0.25 inch; of the usual form, with a distinct row of teeth above, on the anterior portion of each segment, and a few minute bristles at the extremity and along the sides. It is formed within a silken cocoon, constructed in one of the three tubes of the seed, and forces itself halfway out at one side when the moth is about to emerge. (Pl. II, *b;* Pl. III.)

THE EGG.

The egg and newly hatched larva have not heretofore been described. The author's description of the egg follows:

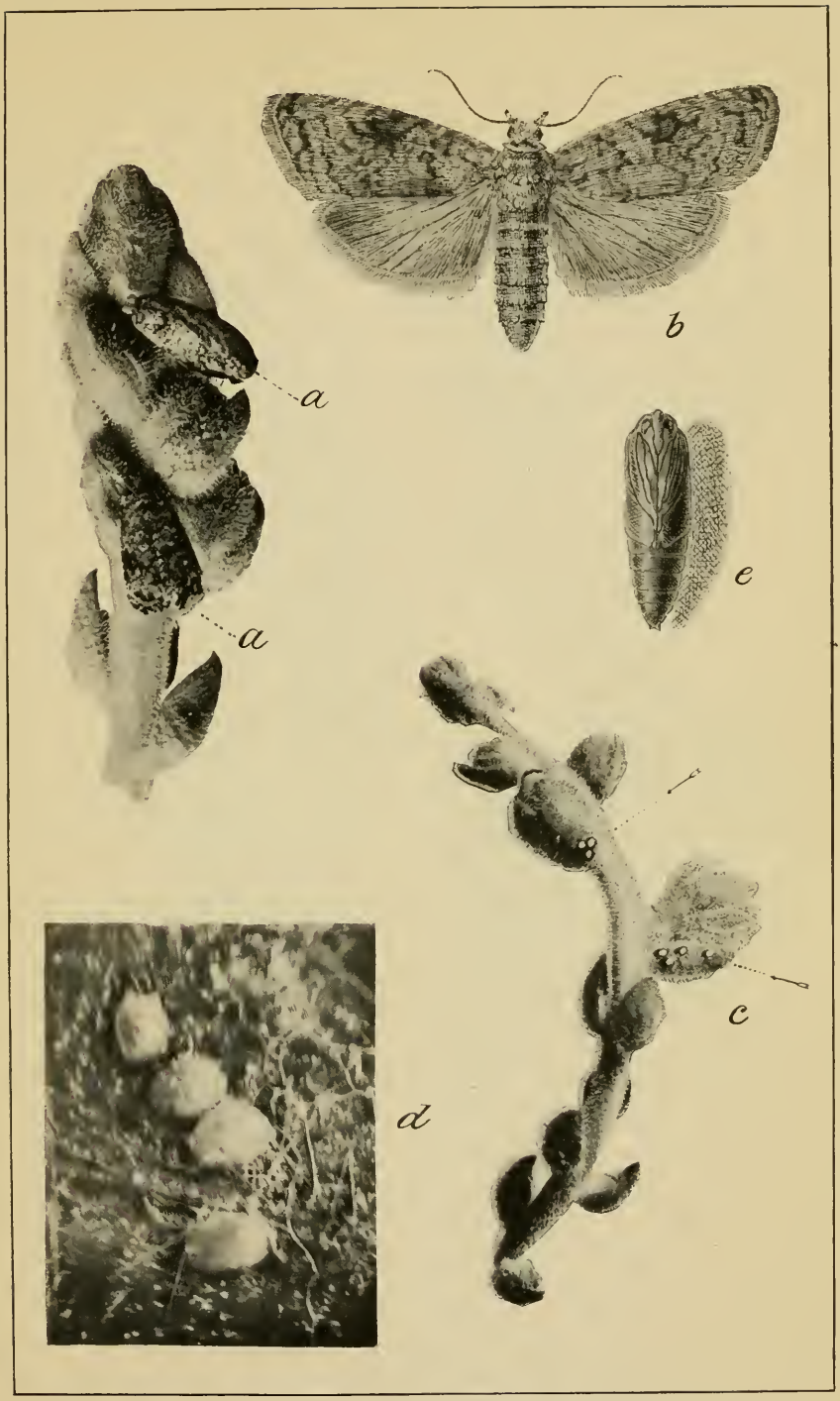
The egg.—The egg is oval with the outline somewhat irregular; long diameter, 0.45 mm., shorter diameter, 0.30. It appears flat below, with the upper surface hemispherical, pitted and also granulated. In color it is usually whitish or light cream and readily distinguishable, particularly when deposited on green sepals. Later the eggs invariably turn slightly reddish, some before hatching taking on a grayish hue.

FIG. 1.—The verbena bud moth: *1*, Larva, ventral view; *2*, larva, lateral view, greatly enlarged. (Original.)

The eggs are deposited singly or sometimes in groups of from three to five on sepals of flower buds, or along the upper part of the tender flower stalk, and hatch in from 7 to 10 days. (Pl. I, *c*, *d*.)

HABITS AND SEASONAL HISTORY.

In the vicinity of Norfolk, Va., and on the grounds of the Virginia Truck Experiment Station the adults of the verbena bud moth, in 1913, began to issue on or about the last week in March. These were



a, MOTHS OVIPOSITING ON ANTIRRHINUM; *b*, FEMALE MOTH, ENLARGED; *c*, EGGS ON BUDS, ABOUT NATURAL SIZE; *d*, EGGS, ENLARGED; *e*, PUPA, ENLARGED. (ORIGINAL.)

THE VERBENA BUD MOTH (OLETHREUTES HEBESANA).

a, FLOWER-STALK SHOWING DROOPING CAUSED BY ATTACK OF LARVÆ, NATURAL SIZE; *b*, SEED CAPSULES SHOWING PUPAL CASES, AND METHOD OF EMERGENCE OF MOTH, ENLARGED. (ORIGINAL.)

WORK OF THE VERBENA BUD MOTH ON ANTIRRHINUM.

SEED CAPSULES OF ANTIRRHINUM WHICH HAVE BEEN ATTACKED BY LARVÆ OF VERBENA BUD MOTH. EMPTY PUPAL CASES EXTRUDED. (ORIGINAL.)

WORK OF THE VERBENA BUD MOTH.

the progeny of overwintering pupæ. On March 30 moths were observed flying about a bed of snapdragon that had been severely infested the previous summer. At this date the flower buds of snapdragons were nearly ready to open.

The moths dart swiftly from plant to plant, but during bright days remain concealed among the plants. Being of a dark color and very small they are inconspicuous and not readily seen without close inspection. (Pl. I, *a*.) In the late afternoon or when the plants are disturbed the moths become active.

Oviposition occurs several days after emergence. On April 2 and 3 egg laying was observed on the flower buds. The moths invariably seek tender flower shoots upon which to oviposit, but according to observation prefer the sepals of flower buds, particularly those situated high up on the plant.

The larvæ as they emerge from the eggshells feed on the tender sepals and petals or on the flower stalk. At this time it is difficult to locate them. After feeding for a while they become more active and then direct their attacks indiscriminately. Some larvæ feed on the sepals and then bore through them, entering the flower and attacking the ovary. Others feed on the petals, stamens, and pistils of the flowers, finally reaching the ovaries. The flower stalk may be attacked by the larvæ, which first mine beneath the epidermis and feed on the juices. Later they may bore into the center of the stalk. (Pl. II, *a*.) They thus give the impression of being able to adapt themselves to many modes of feeding. The seed capsules formed by flowers which have escaped the ravages of the newly hatched larvæ are later vigorously attacked by those half grown. (Pl. III.) The larvæ that bore into the seed capsules continue to feed on the seed within, going from one seed capsule to another, until they have attained their growth. The capsules thus attacked are easily recognized by the small orifices at the base or side and by the excremental castings on the surface. In many instances two such capsules are webbed together by larvæ migrating from one capsule to another. The larvæ are easily alarmed and when disturbed have the interesting habit of thrusting out their heads, and sometimes in their alarm they wriggle out completely, dropping to the ground.

Under laboratory conditions the life cycle occupies 43 days, as follows:

Egg deposited March 2, 1913	Egg state, 8 days.
Larvæ hatched March 10, 1913	Larval state, 21 days.
Pupated March 31, 1913	Pupal state, 14 days.
Adult April 14, 1913	Life cycle, 43 days.

Less time is required during warm weather, as the following will show:

Eggs deposited July 7, 1913	Egg state, 7 days.
Larvæ hatched July 14, 1913	Larval state, 15 days.
Pupated July 31, 1913	Pupal state, 12 days.
Adult August 12, 1913	Life cycle, 34 days.

In the vicinity of Norfolk, Va., at least five or six generations are produced each year. This with the voracious and indiscriminate habit of feeding renders the species a very obnoxious pest when once it has obtained a foothold in a locality. This is particularly true where the production of seed is an object, since plants infested by this insect become worthless.

Besides undergoing all transformation within the seed capsule, the larvæ hibernate within this protection. During the winter larvæ in every stage of development, as well as pupæ, were found concealed in the seed capsules.

METHODS OF CONTROL.

Two methods of control were found effective against the larvæ of the verbena bud moth: (1) Poison spraying against the young larvæ, and (2) cutting back and destroying infested stalks.

SPRAYING.

Two poisons were employed in the spraying experiments.

(*a*) Arsenate of lead, 2 pounds to 50 gallons of water.
Fish-oil soap, 2 pounds to 50 gallons of water.
(*b*) Arsenite of zinc, 1½ pounds to 50 gallons of water.
Fish-oil soap, 2 pounds to 50 gallons of water.

The spraying was done as soon as the larvæ began to hatch and was directed toward the flower buds and young flower stalks. Subsequent investigation developed that from 85 to 90 per cent of the larvæ had been killed. A second spraying followed eight days later, owing to the fact that after the first spraying some moths were observed ovipositing.

CUTTING BACK AND DESTROYING INFESTED FLOWER STALKS.

The nature of the verbena plant is such that during the fall of the year the entire growth may be cut back and new growth will start the following year. In this way the whole brood, including all stages of the pest, is entirely eradicated. If this method is not followed in the fall, one may, in the spring of the year, cut out carefully the infested stalks, and the flower bed should be gone over several times in order to obtain those missed at the time of the first cutting.

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BULLETIN No. 231

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER August 2, 1915.

RECENT STUDIES OF THE MEXICAN COTTON BOLL WEEVIL

By

B. R. COAD, Entomological Assistant, Southern Field Crop Insect Investigations

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INTRODUCTION.

The cotton season of 1913 was of great importance in the study of the boll weevil, *Anthonomus grandis* Boh., because of several opportune discoveries. Briefly, the events of the year were the discovery, by Mr. O. F. Cook, of the cotton boll weevil breeding upon a wild-cotton plant, *Thurberia thespesioides*, in Arizona; the establishment of breeding work at Victoria, Tex., for the purpose of studying any changes in the life history of the weevil; the discovery by the writer of important food adaptations of the weevil; explorations of southeastern Arizona by Dr. A. W. Morrill and Mr. W. D. Pierce in August, by Mr. Vernon Bailey later in the fall, and by Messrs.

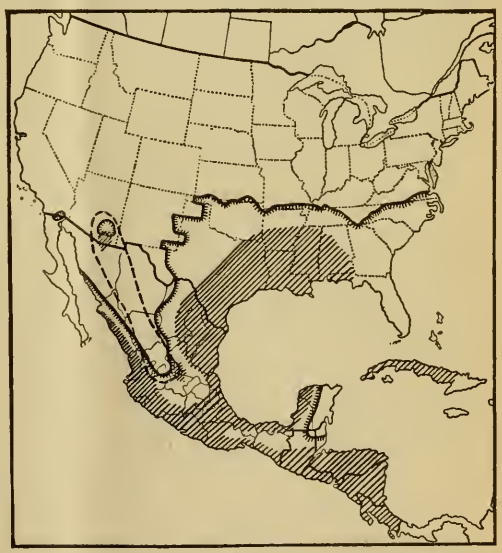

Fig. 1.—Distribution of the Mexican cotton boll weevil. The shading shows the infested area; the heavy lines, the limits of cotton production; the broken line, the probable distribution of the Arizona wild cotton weevil. (Original.)

Note.—This bulletin is of interest to entomologists in the cotton belt.

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E. A. Schwarz and H. S. Barber in December, 1913. The results of the explorations and research work are quite fully treated in the body of this article.

Mr. Cook's announcement, which was published in February, 1913,[1] was followed by departmental press notices issued in October of the same year, and by a detailed article by Mr. W. D. Pierce describing the Arizona weevil as a new variety, *Anthonomus grandis* var. *thurberiæ*, issued November 10, 1913.[2]

A paper by the author on the food habits of the boll weevil in Texas has recently been published.[3]

This bulletin deals with a number of rather technical experiments and observations which have important bearings on the general boll-weevil problem. The principal matters dealt with are, first, the exact relation between the typical boll weevil, *Anthonomus grandis* Boh., and the form *A. grandis thurberiæ* Pierce, which has recently been found attacking a cottonlike plant in Arizona; and, second, the changes in the habits of the boll weevil which have taken place since it first entered the United States.

The importance of the first point mentioned lies in the fact that the western form of the boll weevil has adapted itself to life under extremely arid conditions, in which respect it differs conspicuously from the typical boll weevil. It therefore appears that the western weevil might thrive in the drier portions of Texas, where the typical weevil has not been able to establish itself, and thus reduce the production of cotton in a large area which has been depended upon to offset the loss caused by the boll weevil in more humid regions. Consequently, exact knowledge regarding the life history and habits of the Arizona weevil and its relation to the typical weevil are of importance.

The second matter dealt with in this bulletin, namely, the extent to which the boll weevil has changed its habits since it has been in the United States, is of great practical importance. More than 10 years ago a careful study of the habits of the typical boll weevil was made at Victoria, Tex. The present manuscript deals with similar studies just completed at the same place. These studies give an exact basis for estimating the extent of the departure from the original habits and serve to bring greater accuracy into predictions as to the ultimate nature of the boll-weevil problem in the United States.

DISTRIBUTION.

The discoveries of the year have added to the present knowledge of the distribution of the species. On the accompanying map (fig. 1)

[1] Cook, O. F. A wild host-plant of the boll weevil in Arizona. Science, n. s., v. 27, no. 946, p. 259–261, Feb. 14, 1913.

[2] Pierce, W. D. The occurrence of a cotton boll weevil in Arizona. U. S. Dept. Agr., Jour. Agr. Research, v. 1, no. 2, p. 89–96, Nov. 10, 1913.

[3] Coad, B. R. Feeding habits of the boll-weevil on plants other than cotton. U. S. Dept. Agr., Jour. Agr. Research, v. 2, no. 3, p. 235–245, June, 1914.

it will be seen that there are three apparent lines of distribution of the species, with Costa Rica as the apex. One line of distribution is along the Pacific slope, and although, according to present knowledge, the Arizona infestation is isolated from that of Sinaloa, Mexico, it is probable that the weevil occurs on *Thurberia thespesioides* in the mountains between these points. The Thurberia plant is known from Chihuahua and Guadalajara, Mexico, which latter locality is within a few miles of weevil-infested cotton.

The dispersion following the middle line is historic. Since 1880 this movement has been watched more or less thoroughly from Tamaulipas, Nueva Leon, and Coahuila, Mexico, until now (1914) it has reached the Georgia line (fig. 1).

The third line of distribution from Mexico through Yucatan to central Cuba is the cause of considerable speculation as to whether Cuba or the continent was the original source. There is also some speculation as to whether the Central American infestation furnished the nucleus for the dispersion or whether the weevil originated in southern Mexico and dispersed southward.

FOOD PLANTS.

The plant longest known as the food plant of the boll weevil is cotton, of which several species are now recorded as hosts—*Gossypium hirsutum*, *G. herbaceum*, *G. barbadense*, *G. brasiliense*, and also several Mexican species.

Mr. Cook's announcement added as a native food plant the so-called Arizona wild cotton, *Thurberia thespesioides*, which grows in a number of mountain ranges in southeastern Arizona, and also in parts of Mexico and probably New Mexico.

During the summer of 1913, following the discovery of a boll weevil feeding on cultivated *Hibiscus syriacus* at Victoria, Tex., the writer succeeded in rearing the species on buds of this plant, fed them for some time, and noted the partially complete development in buds of *Callirrhoë involucrata* and *C. pedata*, and kept them alive on *Sphæralcea lindheimeri* buds for a short period.

In the above series of experiments, by alternating foods it was found that the weevils have a wide range of hitherto unsuspected adaptability. This discovery makes the presence of malvaceous plants in the vicinity of cotton a possibly important factor in the ultimate control of the species. The greatest importance of this fact would arise in any attempted cessation of cotton planting as a control measure against the species.

CHOICE OF FOOD PLANT.

Two male and two female boll weevils reared from Thurberia buds imported from Arizona were placed with Thurberia buds and with cotton squares to test their food preference. They began feeding

immediately on both foods, but usually fed slightly more on the cotton squares than on the Thurberia buds. When egg deposition started the greater number of the eggs were deposited in cotton squares. These observations were continued for 15 days.

From these experiments it would appear that, when in captivity, weevils reared from Thurberia will feed on cotton squares just as readily as they will on Thurberia buds. The slightly greater amount of feeding on cotton squares in this experiment may or may not have any significance, and it was probably purely accidental.

These records made in the laboratory are in strong contrast with those made in the field. At Victoria the Thurberia plants under cultivation were within 50 feet of a small patch of cotton. This cotton was heavily infested by weevils throughout the season and not a boll was able to reach maturity. On the other hand, although the Thurberia plants were just as much exposed as the cotton, not a single indication of weevil work was found on the plants and not a weevil was found on them.

In Stone Cabin Canyon, Santa Rita Mountains, Ariz., Mr. W. D. Pierce was unable to find a weevil on cotton plants growing within 10 feet of Thurberia plants which were heavily infested with weevils. In December this same cotton was examined by Messrs. Schwarz and Barber and they were unable to find a sign of weevil work in the bolls.[1]

In this connection records made on the habits of larvæ of the cotton leafworm (*Alabama argillacea* Hübn.) are of interest. These larvæ are almost exclusively cotton feeders, but in the laboratory tests they fed on the Thurberia leaves as readily as on cotton when both were offered and were able to pupate and reach maturity on this food. In Stone Cabin Canyon this species was found feeding on Thurberia plants. The species was common on cotton at Tucson and Phoenix, Ariz. At Victoria, Tex., this species acted exactly as did the native weevils, with relation to the cotton and Thurberia patches. The cotton was heavily infested and only preserved from destruction by spraying, but not a single leafworm larva was ever found on the Thurberia plants. The moths were very numerous for a considerable period and eggs were abundant on the cotton, whereas careful examination failed to show an egg on the Thurberia plants.

CHARACTERISTICS OF THE ADULT.

DESCRIPTION OF THE SPECIES.

Owing to the recent studies on the variations of this species it becomes necessary to reconstruct the descriptions given by Boheman

[1] Experiments during 1914 in Arizona have proven that the Thurberia weevils will attack growing cotton.

and Dietz in order to include all variations. These descriptions are the joint work of Mr. W. D. Pierce and the writer:

Anthonomus grandis Boheman. [Redescribed.]—Stout, subovate to ovate, mahogany red to piceous and clothed with coarse baryta-yellow to raw sienna pubescence. Beak long, slender, shining, and sparsely pubescent at the base; more or less distinctly striate to about the middle; apical half finely and remotely punctured; the beak of the female is slightly longer and more slender than that of the male, more shining, and less coarsely punctured and striate. The female antennæ are inserted at about two-fifths of the distance from the apex of the beak to the eyes, while the male antennæ are inserted at one-third the distance from the apex. Antennæ slender; second joint of funicle longer than the third; joints 3–7 equal in length, but becoming gradually wider. The club may or may not be concolorous with the funicle and is more or less distinctly annulate. Head conical, pubescent, coarsely but remotely punctured, front foveate. Eyes moderately convex, posterior margin not free. Prothorax about one-third wider than long; base feebly bisinuate, posterior angles more or less rectangular; sides almost straight from base to middle, or slightly converging, strongly rounded in front; apex sometimes constricted and transversely impressed behind the anterior margin; surface moderately convex, densely and sometimes subconfluently punctured; punctures irregular in size, sometimes coarser about the sides; pubescence variable, often denser along the median line and on the sides. Scutellum variable. Elytra oblong, scarcely wider at the base than the prothorax; sides convex or subparallel for two-thirds of their length, thence gradually narrowed to and separately rounded at apex, leaving the pygidium moderately exposed; striæ deep, punctures large and approximate; interstices convex, rugulose, pubescence somewhat condensed in spots. Legs rather stout, femora clavate, anterior always strongly bidentate, inner tooth long and strong, outer one variable in shape but connected with former at base; middle and posterior femora unidentate or bidentate. Tibiæ moderately stout, more or less bisinuate internally; tarsi moderate, claws broad, blackish, and rather widely separated; tooth almost as long as claw. Length from 2.3 to 6.75 mm.; width from 1.1 to 3.6 mm.

Anthonomus grandis Boheman. [Typical variety.]—Stout, subovate, almost piceous, and clothed with coarse, baryta-yellow pubescence. Beak long, slender, shining, and sparsely pubescent at base; more or less distinctly striate to about the middle; apical half finely and remotely punctured; the beak of the female is slightly longer and more slender than that of the male, more shining, and less coarsely punctured and striate; the female antennæ are inserted at about three-fifths of the distance from the apex of the beak to the eyes, while the male antennæ are inserted at one-third of the distance from the apex. Antennæ slender, second joint of the funicle longer than the third; joints 3–7 equal in length, but becoming gradually wider; concolorous throughout, usually mahogany red; club rarely distinctly annulate and usually with only the faintest traces of whitish hairs on the apical margins of the first two joints. Head conical, pubescent, coarsely but remotely punctured, front foveate. Eyes moderately convex, posterior margin not free. Prothorax about one-third wider than long, base feebly bisinuate, posterior angles more or less rectangular; sides usually almost straight from base to middle, or slightly converging, strongly rounded in front; apex sometimes constricted and transversely impressed behind the anterior margin; surface moderately convex, densely and sometimes confluently punctured; punctures irregular in size, sometimes coarser on the sides; pubescence condensed in a sharply defined median vitta distinct from base to apex, also denser on sides. Scutellum narrow, elongate, convex, usually cylindrical, rounded oblong. Elytra oblong, scarcely wider at base than the prothorax; sides subparallel for two-thirds of their length, thence gradually narrowed to and separately rounded at apex, leaving the pygidium moderately exposed; striæ deep, punctures large and approximate; interstices convex, rugu-

lose, pubescence somewhat condensed in spots. Legs rather stout, femora clavate, anterior strongly bidentate, inner tooth long and strong, outer one variable but connected with former at base; middle femora unidentate in male, rarely with minute second tooth in female; posterior femora unidentate. Tibiæ moderately stout, more or less bisinuate internally; tarsi moderate, claws broad, blackish, and rather widely separated; tooth almost as long as claw. Length, from 2.3 to 6.75 mm.; width, from 1.1 to 3.6 mm.

Anthonomus grandis thurberiæ Pierce.—Stout, ovate, mahogany red, and clothed with coarse, raw sienna pubescence. Beak long, slender, shining, and sparsely pubescent at base; more or less distinctly striate to about the middle; apical half finely and remotely punctured; the beak of the female is slightly longer and more slender than that of the male, more shining and less coarsely punctured and striate; the female antennæ are inserted at about two-fifths of the distance from the apex of the beak to the eyes, while the male antennæ are inserted at one-third of the distance from the apex. Antennæ slender, second joint of funicle longer than the third; joints 3–7 equal in length but becoming gradually wider; the club piceous black, scape and funicle mahogany red; club with apical margins of the first two segments usually distinctly annulate with fine whitish hairs. Head conical, pubescent, coarsely but remotely punctured, front foveate. Eyes moderately convex, posterior margin not free. Prothorax about one-third wider than long; base bisinuate, posterior angles more or less rectangular; sides usually converging from near base to apical third and thence strongly convexly narrowed to apex; apex sometimes constricted and transversely impressed behind the apical margin; surface moderately convex, densely and sometimes subconfluently punctured, punctures irregular in size, sometimes coarser about the sides; pubescence evenly distributed; without sharply defined vittæ. Scutellum broad, subquadrate, rarely subtriangular, flattened. Elytra broad, scarcely wider at the base than the prothorax; sides slightly convex in basal two-thirds, thence strongly convexly narrowed and separately rounded at apex, leaving the pygidium moderately exposed; striæ deep, punctures large and approximate; interstices convex, rugulose, pubescence more regular but slightly condensed in spots. Legs rather stout, femora clavate, anterior always strongly bidentate, inner tooth long and strong, outer one variable in shape but connected with former at base; middle femora bidentate; posterior femora almost always unidentate. Tibiæ moderately stout, anterior and median bisinuate internally, posterior straight; tarsi moderate, claws broad, blackish, and rather widely separated, tooth almost as long as claw. Length, from 2.5 to 6.7 mm.; width, from 1.8 to 3.6 mm.

LONGEVITY OF ADULT WEEVILS.

Several series of experiments were conducted to determine the longevity of the weevils upon different foods. These experiments not only compare the two varieties of the weevil, but compare weevils from Tallulah, La., with those from Victoria, Tex.; various Malvaceæ with one another and with a diet of water only; different parts of the same plant; different seasons; and also the two sexes. The data obtained are presented in concise form in Table I.

The maximum record of longevity made in the 1913 work is based on a specimen of *Anthonomus grandis thurberiæ*, extracted from its hibernation cell August 27, after at least nine months in hibernation, which was still alive when the food supplies at Victoria gave out, October 29. This gives the maximum known period of hibernation as 270 days, and a total of over 333 days longevity. The maximum recorded length of life is 335 days for a hibernated weevil at Tallulah, La., in 1910.[1]

The maximum length of life of weevils after emergence from hibernation was 73 days for males and 71 days for females, both of which records are far below the highest previous records.

A true comparison of females fed on blooms of *Hibiscus syriacus* gives the average longevity of Arizona *A. g. thurberiæ* as 22.5 days, Texas *A. grandis* as 16 days, and Louisiana *A. grandis* as over 27 days.

The *grandis* males averaged 3.47 days on water, 5 days on *Sphæralcea lindheimeri*, 7.6 days on *Callirrhoë pedata*, 17.5 days on *Hibiscus syriacus*, 20 days on *Callirrhoë involucrata*, and 33.2 days on cotton, while the *thurberiæ* males averaged 27.6 days on *Hibiscus syriacus*.

The *grandis* females averaged 3.32 days on water, 5.4 days on both *Sphæralcea lindheimeri* and *Callirrhoë pedata*, 19.2 days on *Hibiscus syriacus*, and 34.3 days on cotton, while the *thurberiæ* females averaged 25.5 days on *Hibiscus syriacus*.

The greater longevity of weevils on the same food later in the season is very evident and is due to the advance of hibernation temperatures.

Although the records of life on cotton were shorter than those previously obtained when the totals are considered, it is noted that they agree quite well for any given season. It is evident that temperature and humidity exercise considerable control upon the length of life on any given food. The average longevity on cotton leaves was 11.9 days, on bolls 17.2 days, and on squares 42.1 days.

Adding these new records to those previously obtained 5,858 weevils fed on water only averaged 10.1 days; 16 weevils fed on cotton leaves only averaged 11.9 days; 226 weevils fed on miscellaneous malvaceous plants averaged 13.2 days; 92 weevils fed on cotton bolls averaged 19.9 days; 4,353 weevils fed on cotton foliage averaged 24.5 days; and 147 weevils fed on cotton squares averaged 59.5 days.

Comparing the sexes irrespective of food in all experiments hitherto conducted 4,226 males averaged 17.7 days, and 3,624 females averaged 18.5 days.

[1] The longevity records of 1913 have been greatly exceeded during 1914 in experiments conducted at Washington, D. C. Weevils have been kept in a dormant state for over a year, and give promise of living considerably longer.

TABLE I.—*Duration of life of boll weevils.*

VARIETY GRANDIS, WITHOUT NORMAL FOOD.

Season.	Sustenance provided.	Males.				Females.				Both sexes.		Notes on weevils.
		Number.	Weevil[1] days.	Average longevity.	Maximum longevity.	Number.	Weevil[1] days.	Average longevity.	Maximum longevity.	Maximum longevity.	Average longevity.	
				Days.	*Days.*			*Days.*	*Days.*	*Days.*	*Days.*	
June 22–July 2	Moist sand	19	66	3.17	6	21	70	3.32	5	6	3.3	Bred.
May 13–May 28	*Sphæralcea lindheimeri*, buds and blooms.	3	22	7.3	9	3	30	10.0	15	15	8.6	Hibernated.
June 13–June 29	do	10	43	4.3	8	10	41	4.1	7	8	4.2	Bred.
Total on Sphæralcea.		13	65	5.0	9	13	71	5.4	15	15	5.2	
May 16–June 11	*Callirrhoë pedata*, buds and blooms.	4	56	14.0	26	4	41	10.2	18	26	12.1	Hibernated.
June 13–July 6	do	11	58	5.3	21	11	40	3.6	6	21	4.4	Bred.
Total on *Callirrhoë pedata*.		15	114	7.6	26	15	81	5.4	18	26	6.5	
May 13–June 2	*Callirrhoë involucrata*, buds and blooms.	1	20	20.0	20	.....	.....	.....	.....	20	20.0	Hibernated.
June 26–July 1	*Hibiscus syriacus*, buds	5	16	3.2	5	5	21	4.2	5	5	3.7	Bred.
June 26–Aug. 5	*Hibiscus syriacus*, blooms	4	120	30.0	40	2	32	16.0	28	40	25.3	Do.
Sept. 1–Oct. 13	do	2	+66	+33.0	+33	2	+54	+27.0	+33	+33	+30.0	Bred. Tallulah weevils.[2]
June 16–July 22	*Hibiscus syriacus*, buds, blooms, and fruit.	6	92	15.3	23	6	101	16.8	36	36	16.0	Collected.
July 16–July 28	do	6	91	15.1	26	6	140	23.3	43	43	19.2	Bred.
Aug. 28–Sept. 23	do	3	27	9.0	13	3	58	19.3	26	26	14.1	Do.
Sept. 9–Oct. 13	do	3	+97	+32.3	+34	4	+133	+33.3	+34	+34	+32.8	Do.[2]
Total on Hibiscus		29	+509	+17.5	40	28	+539	+19.2	43	43	+18.3	
Total all *grandis*	Abnormal malvaceous foods.	58	+708	+12.2	40	56	+691	+12.3	43	43	+12.2	

[1] "Weevil days" is the term applied to the sum of the time periods experienced by the various individuals during the course of the observations.
[2] These weevils were alive on October 13 when the food supply ran out.

VARIETY THURBERIÆ, WITHOUT NORMAL FOOD.

Season.	Sustenance provided.	Males.				Females.				Both sexes.		Notes on weevils.
		Number.	Weevil[1] days.	Average longevity.	Maximum longevity.	Number.	Weevil[1] days.	Average longevity.	Maximum longevity.	Maximum longevity.	Average longevity.	
				Days.	*Days.*			*Days.*	*Days.*	*Days.*	*Days.*	
Sept. 5–Oct. 18	*Hibiscus syriacus*, blooms					2	45	22.5	30	30	22.5	Bred.
Sept. 9–Oct. 13	*Hibiscus syriacus*, buds, blooms, and fruit.	5	+138	+27.6	+34	4	+108	+27.0	+34	+34	+27.3	Do.[2]
Total all *thurberiæ* on Hibiscus.		5	+138	+27.6	+34	6	+153	+25.5	+34	+34	+26.4	

VARIETY GRANDIS, WITH NORMAL FOOD.

June 9–July 24	Cotton, leaves	8	121	15.2	45	8	70	8.8	13	45	11.9	Bred.
June 18–July 20	Cotton, bolls	4	96	24.0	32	6	76	12.6	30	32	17.2	Do.
May 8–Aug. 1	Cotton, squares	10	497	49.7	73	13	556	42.8	71	73	45.6	Hibernated.
June 5–Oct. 10	do	9	318	35.3	52	32	1,325	41.4	74	74	40.0	Bred.
Total all *grandis* on cotton.		31	1,032	33.2	73	59	2,027	34.3	74	74	32.8	

[1] "Weevil days" is the term applied to the sum of the time periods experienced by the various individuals during the course of the observations.
[2] These weevils were alive on October 13 when the food supply ran out.

It is important to note that the maximum longevity on water was 6 days, on *Sphæralcea lindheimeri* 15 days, on *Callirrhoë involucrata* 20 days, on *C. pedata* 26 days, on *Hibiscus syriacus* 43+ days, and on cotton 74 days.

SEX OF ADULTS.

The material studied during the year was all sexed and the records have been tabulated to show the seasonal abundance and for comparison of the varieties (Table II).

TABLE II.—*Relative proportions of the sexes of boll weevils.*

Variety and description of material.	Male.		Female.	
	Number.	Per cent.	Number.	Per cent.
Grandis:				
Hibernated weevils	674	67.88	319	32.12
First generation collected	73	53.3	64	46.7
Collected in August	158	62.0	97	38.0
Bred	557	52.6	500	47.4
Total and average	1,462	59.8	980	40.2
Thurberiæ:				
Collected in August	21	51.3	20	48.7
Bred from Thurberia bolls in September	11	50.0	11	50.0
Bred from cotton in the fall	20	62.5	12	37.5
Extracted from Thurberia bolls, March, 1914	71	57.7	52	42.3
Total and average	123	56.9	95	43.1
Hybrids:				
♂ *Thurberiæ* × ♀ *grandis*	22	59.4	15	40.6
Second generation	21	42.0	29	58.0
Not positive crosses	135	51.0	130	49.0
♂ *Grandis* × ♀ *thurberiæ*	11	45.8	13	54.2
Second generation	15	57.7	11	42.3
Not positive crosses	20	51.3	19	48.7
Total and average	224	50.7	217	49.3
Total and average all weevils	1,809	58.3	1,292	41.7

Separating this material into hibernated and spring or summer bred weevils, there are in the hibernated material 777 males and 402 females, or 65.9 per cent males and 34.1 per cent females, while the spring and summer bred weevils numbered 1,032 males and 890 females, or 53.6 per cent males and 46.4 per cent females.

The total of all records to date gives 8,826 males and 6,710 females, or 56.7 per cent males and 43.3 per cent females.

It is noticeable that there is a larger percentage of females in the variety *thurberiæ* and in the hybrids than in the variety *grandis*.

REPRODUCTION.

RELATION OF FOOD TO COPULATION.

To test the period from emergence to copulation, a number of lots of males and females of the variety *A. grandis* were separated by sexes immediately after emergence and placed on either cotton

squares, leaves, or bolls. In each lot the weevils were paired off together for a few hours daily while under close observation. As soon as a pair copulated they were removed from the lot and the remainder tested until they either copulated or died. In this copulation series 23 pairs of weevils fed on squares, 2 pairs fed on bolls, and 1 pair fed on leaves copulated. These figures are of more value when taken in relation to the number of pairs of weevils that refused to copulate before death on the different foods. This relation is shown in Table III.

TABLE III.—*Relative proportion of boll weevils copulating on different foods.*

Food.	Number pairs of weevils carried to either copulation or death.	Number pairs copulated.	Percentage copulated.
			Per cent.
Cotton squares	38	23	60
Cotton bolls	8	2	25
Cotton leaves	8	1	12

From this table it is seen that copulation is unusual when the weevils are fed strictly on either cotton bolls or leaves.

AGE AT WHICH FERTILIZATION TAKES PLACE.

The length of the period before copulation depends in a large measure upon the temperature as well as upon the food. For square-fed weevils this period varied from 3 to 10 days, with a weighted average of 5.8 days.

In the series of boll-fed weevils only two records were made on this period. Both of these were in the latter part of June and were 6 and 8 days, respectively, giving an average of 7 days.

In the leaf-fed series only 1 pair copulated, and they gave a period of 5 days.

The records on boll-fed and leaf-fed weevils are too few in number to offer any comparison with the length of the period for square-fed weevils and serve only to emphasize the difficulty with which the life functions are performed on these unnatural foods.

The period from emergence to copulation was not determined exactly for the weevils fed only on buds and blooms of *Hibiscus syriacus*, but some idea of the period can be secured from the first date the weevils were observed in copula while making the daily examination. Two pairs of *A. g. thurberiæ* were first observed in copula in 6 and 14 days after emergence, while at the same time (September) two pairs of *A. grandis* were first observed in copula in 9 and 13 days after emergence. These records and the frequency with which the weevils were observed in copula later show that the proper element to stimulate copulation is present in the food.

PERIOD FROM FERTILIZATION TO OVIPOSITION.

The period from fertilization to oviposition was secured as a continuation of the experiments described under the period from emergence to copulation. After the females in this series copulated once they were placed on food and watched for the first egg deposited. In this manner the period was determined. In most cases the male was removed after the first fertilization, but in a few cases the male was placed with the female for a short period each day and the copulation noted. In this way as many as five copulations were noted for a female before a single egg was deposited. The periods determined are noted according to the food.

Weevils fed on cotton squares.—During June, July, and August this period was observed for 21 females fed only on squares. The period ranged from 1 to 7 days, with an average of 3.9 days.

Weevils fed on cotton bolls.—Three pairs of boll-fed weevils were observed from first copulation to oviposition. The period for these weevils ranged from 3 to 7 days, with an average of 5 days.

Weevils fed on cotton leaves.—Only one pair of weevils started copulating when fed only on cotton leaves from emergence. This female emerged July 7 and copulated the first time on July 11. She lived until July 24 and copulated 8 times in the interval. No eggs were laid.

PERIOD FROM EMERGENCE TO OVIPOSITION.

In the series of typical *grandis* the period from emergence to oviposition when on squares constantly varied from 3 days to 13 days, with an average of 6.1 days for the positive records.

With typical *thurberiæ* the three cases recorded ranged from 3 to 6 days, with an average of 4 days. These records are too few in number to allow a positive comparison with those for *grandis*, but the average is just about the same as for the latter during the same period (early September).

Two pairs of progeny of female *grandis* by male *thurberiæ* began to oviposit in 4 and 7 days each or an average of 5.5 days.

Two pairs of progeny of female *thurberiæ* by male *grandis* began to oviposit in 5 days each.

The period from emergence to oviposition was observed with six pairs of *grandis* fed only on buds and blooms of *Hibiscus syriacus* from maturity. Three of these pairs observed during early June varied from 5 to 6 days, and averaged 5.6 days. The other three pairs, observed during September, ranged from 11 to 18 days, with an average of 13.6 days.

This period was also observed with two pairs of *thurberiæ* on the same food. These began to oviposit in 12 and 16 days, or in an average of 14 days.

PERIOD FROM FIRST FEEDING ON SQUARES TO OVIPOSITION.

The period from first feeding on squares to oviposition is shown for hibernated *A. grandis* females in Table IV.

TABLE IV.—*Time from first feeding on squares to oviposition for hibernated females of A. grandis.*[1]

Collected, May—	First fed on squares, May—	First eggs deposited, May—	Period fed on squares to deposition.	Total period from first fed on leaves to deposition.
			Days.	*Days.*
8	14	22	8	14
8	14	19	5	11
8	15	20	5	12
8	17	19	2	11
10	24	25	1	15
Avg.			4.2	12.6
Max.			8	15
Min.			1	11

[1] These weevils were collected in the field before squares began to form and fed upon leaves until the dates noted above.

The weevils were collected in the field before any squares were formed and were fed only on cotton leaves until the dates given for placing on squares. It is seen that the period ranged from 1 to 8 days with an average of 4.2 days. An interesting point, however, is the fact that the time from the change from leaves to squares as food to the beginning of oviposition seems to vary inversely with the time fed on leaves. The totals of these two periods or, in other words, approximately the time from first feeding on the cotton plant to oviposition, are surprisingly similar. They vary from 11 to 15 days with an average of 12.6 days.

This period for female *thurberiæ* paired with male *grandis* was 12 and 15 days in the two cases tested in May and June. This gives an average of 13.5 days. In early September this period ranged from 2 to 5 days with an average of 3 days.

During the early part of September this period for typical *thurberiæ* varied from 1 to 3 days with an average of 2.2 days.

In all these series where female *thurberiæ* were used the individuals were extracted from their hibernation cells in Thurberia bolls and placed on cotton squares immediately.

The period from first feeding to oviposition of early hibernated females was observed in only one pair of weevils fed on the buds and blooms of *Callirrhoë pedata*. This female began depositing eggs 6 days after being placed on this food. As these weevils were collected during the early part of May they had probably fed very little, if at all, on cotton.

DURATION OF FERTILITY AND FECUNDITY.

Many experiments were conducted to test the duration of fertility and the fecundity of the various types of weevils. With *A. grandis* special experiments on this question were conducted in addition to the regular breeding series. Rather thorough data were obtained on the variety *thurberiæ* and the various crosses in the different breeding series of these.

Fecundity of females of A. grandis in copula only once.—The previous results on the exact duration of the fertility of females after copulation were very indefinite and there were no records of the fecundity resulting from only one copulation. In the course of the past summer's investigations the writer was able to secure considerable information on this point.

Eleven females were separated from the males immediately after emergence and only returned to them about 6 hours each day when under close observation. In this manner the first copulation of each female was determined and she was then placed alone on squares to test her fecundity with no more chances for fertilization. Of the 11 females so treated, five were fertile, four were infertile but deposited eggs, and two failed to deposit any eggs. Of the two that did not deposit eggs, one was in copula 25 minutes and the other 10 minutes. Each of these lived a short time and then died. The fecundity tests of the remainder gave the results found tabulated in Tables V and VI.

TABLE V.—*Fecundity of females of A. grandis in copula only one time and rendered fertile in that time.*

Duration of fertility.	Time in copula.	Oviposition.			Total eggs.	Eggs deposited.		Eggs per day.	
		Started.	Ended.	Period.		Externally.	Normally.	Average.	Maximum.
	Minutes.			*Days.*					
To end of oviposition	24	June 28	Aug. 7	41	348	0	348	8.5	17
To Aug. 10	[1] 45	...do....	Aug. 27	61	456	9	447	7.4	21
To end of oviposition	26	June 30	July 18	19	87	0	87	4.6	7
Do	[2] 31	July 12	Aug. 12	32	237	0	237	7.4	17
Do	29	Aug. 9	Sept. 4	27	32	0	32	1.2	3
Total	155	.....	.....	180	1,160	9	1,151	.....	.....
Average	31	.....	.....	36	235	.....	.....	.....	.....
Weighted average	.....	.....	.....	.....	.....	.....	.....	6.4	.....
Maximum	45	.....	.....	61	456	9	447	8.5	21
Minimum	24	.....	.....	19	32	0	32	1.2	3

[1] Copulated twice (22 and 23 minutes respectively) with interval of 12.5 minutes between copulations.
[2] Copulated four times (7, 4, 2, and 18 minutes respectively) between 10:04 a. m. and 11:18 a. m. Remainder of the weevils were in copula only one time. These copulations were with so very little time between them that they were considered as one fertilization.

TABLE VI.—*Fecundity of females of A. grandis in copula only one time and not fertilized.*

Total, average, etc.	Time in copula.	Oviposition.			Total eggs.	Eggs deposited.		Eggs per day.		Time from last egg to death.
		Started.	Ended.	Period.		Externally.	Normally.	Average.	Maximum.	
	Min.			*Days.*						*Days.*
.....	3	June 29	June 29	1	1	0	1	1	1	4
.....	7.5	June 30	Aug. 26	58	67	51	16	1.1	6	1
.....	19	July 1	July 1	1	3	0	3	3	3	8
.....	37.5	...do....	July 3	3	3	0	3	1	1	35
Total...	67.0	.....	.....	63	74	51	23	.....	.....	48
Average.....	16.7	.....	.....	15.7	18.5	.....	.....	.....	.....	12
Weighted average.....	.....	.....	.....	.....	.....	.....	.....	1.1	.....	.....
Maximum....	37.5	.....	.....	58	67	51	16	3	6	35
Minimum.....	3	.....	.....	1	1	0	1	1	1	1

From Table V it is seen that the greatest fertility was with the longest period of copulation (45 minutes). Beyond this there seems to be very little relation between the time in copula and the resulting degree of fertility. In the infertile females it is seen that periods of 25 and 37.5 minutes in copula still failed to result in fertility.

The total eggs deposited by the fertile females ranged from 32 to 456 with an average of 235 each for the five females. This average is quite high, even in comparison with females having males present throughout life. The infertile females deposited from 1 to 67 eggs, with only one depositing more than 3 eggs.

The period of fertility of the fertile females ranged from 19 to 44 days with an average of 32.6 days. The average eggs per day ranged from 1.2 to 8.5 with a weighted average of 6.4. This is a rather high average when compared with the results secured in other deposition series.

A comparison of these results seems to indicate that the time in copula has very little influence on the resulting fertility of the female. One female was not rendered fertile during 37.5 minutes of copulation while four others were fertilized in less than this time. The shortest time in copula which resulted in fertility of the female was 24 minutes, but the writer thinks that this is not significant.

The high average of the eggs deposited by the females fertilized only once would seem to indicate that one fertilization is sufficient to produce the maximum fecundity of the female. While this may be true in certain rare instances, the writer believes that such cases will be very rare. In a different breeding series a few females were allowed to deposit eggs from one fertilization until they stopped deposition, then males were added and in every case the females began depositing again and continued for some time. The female with the highest deposition record in the one fertilization series discussed above quite evidently reached the limit of her fertility 17 days before death and she deposited 9 infertile eggs in this period.

From this evidence it seems clear that one copulation will often result in fertilization, but will not usually suffice for complete fecundity of the female.

Fecundity of females of A. grandis with complete record on copulation.—Since very little was known concerning the exact number of times a single female will copulate in the course of her life an attempt was made to secure some information on this point.

Nine females were separated from the males immediately after emergence and each was fed separately throughout life. A male was allotted to each female and each day the different pairs were placed together in dry glass tubes for a short time while under close observation and given a chance to copulate. The period spent in copula was noted each time and in this manner a complete record of the copulations of each female was secured. During the remainder of the day the females were kept on fresh squares and the daily egg deposition noted. The results secured in this series are shown in Table VII.

TABLE VII.—*Fecundity of females of A. grandis with complete record of time in copula.*

Total, average, etc.	Times in copula.	Total time in copula.	Average time per copula.	Oviposition.			Total number eggs.	Eggs deposited externally.	Average number eggs per day.	Maximum number eggs per day.
				Started.	Ended.	Period.				
		Min.	*Min.*			*Days.*				
	22	490.5	22.3	July 2	July 29	28	204	0	7.3	13
	30	667.5	22.2	July 4	Aug. 9	37	217	0	5.8	18
	33	786.5	23.8	...do.....	Aug. 24	52	302	4	5.8	15
	27	689.0	25.5	July 5	Aug. 4	31	112	0	3.6	10
	29	650.5	22.4	July 6	Aug. 12	38	126	2	3.3	10
	24	563.0	23.4	July 7	Aug. 6	31	126	1	4.0	10
	18	369.0	20.5	...do.....	Aug. 7	32	208	0	6.5	14
	13	291.5	22.4	July 9	Aug. 5	28	65	0	2.3	10
	9	196.0	21.7	July 11	Aug. 27	17	32	0	1.9	5
Total	205	4,703.5	.....	.....	.....	294	1,392	7	.....	.....
Average	22.7	522.6	22.9	.....	.....	32.7	154.7	.....	.....	.....
Weighted average	.....	.....	.....	.....	.....	.....	.....	.....	4.7	.....
Maximum	33	786.5	25.5	.....	.....	52	302	4	7.3	18
Minimum	9	196.0	20.5	.....	.....	17	32	0	1.9	5

The number of times a single female will copulate was found to be much higher than was anticipated. With these 9 females the number varied from 9 to 33, with 6 females copulating more than 20 times. The average per female was nearly 23 times.

In spite of the great number of copulations the number of eggs deposited by these females was not high in comparison with other series. It may be that the fact that the females were of necessity removed from their food for from 1 to 2 hours daily while with the males had some effect on the egg deposition. The total number of eggs per female varied from 32 to 302, with an average of 154.7 eggs per female. This average is considerably lower than that for the females fertilized only once The average number of eggs per female per day was 4.7, which is also lower than the average for the once fertilized females.

When the male and female weevils were placed together in the dry tubes daily they very rarely failed to copulate. They would usually unite within a few minutes after being being placed in the tube and it was very rarely that they copulated at all if they did not start almost immediately after having the opportunity. It was extremely rare for the two sexes to remain together without copulation for a half hour and then unite.

The various breeding series in which one pair of weevils were together on squares were examined only once daily and many pairs were found in copula day after day when making these daily examinations. In the field it was very noticeable that a pair usually united as soon as they were placed together on a plant. When weevils are collected in the field and placed in a tube it is the common occurrence for many pairs to unite as soon as dropped in the tube. Hence it seems probable that it is normal for a single female to be in copula many times and for the weevils to copulate almost whenever they meet in the course of their travels over the plants.

Three females deposited a total of 7 eggs externally. These eggs were deposited during the days when the same females deposited other eggs normally. As the females were certainly fertile, owing to the almost daily copulations, this shows that external deposition of eggs may be due to some cause other than infertility. The eggs deposited externally by these females were tested for viability and all hatched.

Fecundity of A. grandis females after hibernating.—Twelve females were collected in the field at Victoria, Tex., May 8 to 10, shortly after emergence from hibernation, and fed on cotton leaves until squares became available. Then each was placed with a male and given fresh squares daily for oviposition. These females were all observed until their normal death. The results secured are shown in Table VIII:

TABLE VIII.—*Fecundity of females of A. grandis after hibernating.*

Number of females.	Total eggs laid.	Average eggs per female.	Approximate oviposition period per female.	Eggs per day.	
				Average.	Maximum.
			Days.		
2	144	72	12	6.0	14
2	673	336.5	32	10.5	[1] 20
1	302	302	53	5.7	12
2	336	168	25	6.7	11
2	715	357.5	55	6.5	12
2	701	350.5	46	7.6	19
1	100	100	13	7.6	11
Total, 12	2,971	.....	406	.....	.....
Average	.....	247.6	33.8	.....	.....
Weighted average	.....	.....	.....	7.3	.....
Maximum	.....	358	55	10.5	20
Minimum	.....	72	12	5.7	11

[1] The 2 females in this lot deposited 39 eggs in 1 day. Therefore one of them laid at least 20 eggs.

Unfortunately 10 of these females were placed 2 to a breeding cage, and consequently the records for each of these cages give the activities of 2 females instead of 1. Therefore complete individual records of these females can not be given.

The total number of eggs deposited by these weevils is very high. The average per female in the different lots ranged from 72 to 358 eggs. The average for the 12 females is 247.6 eggs. These averages are considerably higher than those of the reared weevils of the later generations. It was previously supposed that, owing to the vitality used in passing the winter, hibernated females would deposit less eggs than weevils emerged during the summer, but this is shown not to be the case.

The previously recorded maximum number of eggs deposited by a single female was 304. It is of considerable interest to note that 6 out of these 12 hibernated females evidently exceeded that number. The average number of eggs per day ranged from 5.7 to 10.5, with an average of 7.3. This also is greater than the average of any of the later generations.

Fecundity of summer-reared weevils.—Although the greater part of the females used in the various generation series of *A. grandis* during the season were not allowed to complete oviposition, 7 of them were continued to completion. The activities of these females are shown in Table IX.

TABLE IX.—*Fecundity of females of A. grandis in various breeding series throughout the season.*

Source of weevils.	Oviposition—			Total eggs.	Eggs per day.	
	Started.	Ended.	Period.		Average.	Maximum.
			Days.			
First generation adults	June 18	July 12	25	205	8.2	14
Third generation adults	July 26	Sept. 30	67	141	2.1	10
Do	...do	Aug. 10	16	83	5.2	12
Do	...do	Sept. 23	60	205	3.4	12
Last adults of first generation	Aug. 3	Sept. 30	59	233	3.9	11
Fourth generation adults	Aug. 18	...do	44	153	3.5	12
Do	...do	...do	44	45	1.0	5
Total				1,065		
Average			45	152.1		
Weighted average					3.3	
Maximum			67	233	8.2	14
Minimum			16	45	1.0	5

Considering the fact that these females were with males constantly, were given fresh squares daily and were less disturbed than any others, it is surprising that their oviposition was so low. The maximum did not equal the average of the once copulated weevils and the average is nearly 100 less than the average for the hibernated females.

The average number of eggs per day ranged from 1 to 8.2, with an average of 3.3 eggs. This is also much less than the average for either the hibernated or once copulated weevils. The maximum number of eggs per day ranged from 5 to 14. In fact these weevils showed a surprisingly low degree of fertility in all points.

Fecundity of females of A. grandis in experiments not continued to completion.—Many of the females in the various *grandis* generation series were allowed to oviposit only a short time and then stopped because of lack of squares. Some interesting data were secured from some of these weevils, as is shown in Table X.

TABLE X.—*Fecundity of females of A. grandis in experiments not continued to completion.*

Oviposition started.	Experiment closed.	Oviposition.	Total eggs.	Eggs per day.	
				Average.	Maximum.
		Days.			
June 16	June 20	5	20	5.0	7
June 17	July 2	16	147	9.2	15
Do	July 11	25	318	12.7	26
July 7	July 12	6	45	7.5	11
Do	...do	6	99	16.5	21
July 9	...do	4	31	7.7	11
Sept. 8	Sept. 21	14	53	3.7	8
Sept. 9	...do	13	73	5.6	10
Maximum				16.5	26
Minimum				3.7	7

This information is of principal value in giving maximum and minimum records. One female in this lot gave the season's maximum record for eggs deposited in one day. This was 26 eggs. Incidentally this is the highest number of eggs deposited by a single female in one day on record. This female was allowed to continue deposition only 25 days, but in this time she deposited a total of 318 eggs, or an average of 12.7 per day.

Fecundity of typical A. g. thurberiæ fed on cotton squares.—Three pairs of pure *thurberiæ* were mated on cotton squares in June, but for some reason only one female deposited any eggs. This one deposited 7 eggs with a maximum of 4 in 1 day and an average of 0.3 per day. These eggs were probably all fertile, as most of them, at least, hatched. It is very hard to account for the fact that two of these females laid no eggs and the other deposited so few. The females of *thurberiæ* placed with *grandis* males at this same time deposited a normal number of eggs.

The fall series of pure *thurberiæ* mated on cotton squares gave much better results, as is shown in Table XI.

TABLE XI.—*Fecundity of typical A. g. thurberiæ.*

Number of females.	Oviposition.			Total eggs.	Eggs per day.		Mean temperature for period.
	Started.	Ended.	Period.		Average.	Maximum.	
			Days.				° *F.*
1[1]	Sept. 7	Sept. 7	1	1	1.0	1	.....
1	Sept. 3	Oct. 6	34	173	5.1	17	77.6
1	Sept. 2	Oct. 1	30	73	2.4	11	77.3
1	...do.....	Oct. 2	31	90	3.0	8	77.4
1	Sept. 4	Oct. 6	33	76	2.3	8	77.4
Total	.....	.....	128	412	.....	.....	.....
Average	.....	.....	32	103	.....	.....	.....
Weighted average	.....	.....	.....	.....	3.2	.....	77.4
Maximum	.....	.....	34	173	5.1	17	.....
Minimum	.....	.....	30	73	2.3	8	.....

[1] Owing to the fact that this female deposited only one egg, the record is not included in the averages and summary given.

Five pairs were mated, and while four females deposited fairly well, the other deposited only one egg and is not considered in the following discussion. The total number of eggs deposited by these females ranged from 73 to 173, with an average of 103. The average per day ranged from 2.3 to 5.1, with an average of 3.2, and the maximum in one day was 17. All of these records are very low in comparison with the results of practically all other series. On the other hand, the *thurberiæ* females mated with *grandis* males at this time gave better deposition records.

Results of the mating of male of A. g. thurberiæ and female of A. grandis.—In June two hibernated *grandis* females collected in the field were placed with male *thurberiæ* on cotton squares. As these females were undoubtedly fertilized by *grandis* males before being isolated, this series did not result in positive proof of cross breeding, but, as the weevils copulated freely, the later progeny were quite probably hybrids.

These two females deposited 192 and 387 eggs, respectively, with an average of 7.1 and 7.9 each per day. The average total number of eggs per female was 289.5 and the daily average was 7.6. The maximum number of eggs per day was 16 for each female. On the whole this fecundity is quite high and the females were surely refertilized by the new type of males.

In September three known infertile females of *grandis* were mated with male *thurberiæ* on cotton squares immediately after emergence. This resulted in the positive crossing of the two. The results of these matings are shown in Table XII.

TABLE XII.—*Fecundity of positive crosses of male of thurberiæ and female of grandis.*

Total, average, etc.	Number of females.	Oviposition.			Total eggs.	Eggs per day.		Average temperature for period.
		Started.	Ended.	Period.		Average.	Maximum.	
				Days.				°*F.*
	1	Sept. 7	Oct. 24	48	115	2.4	7	74.4
	1	Sept. 4	Sept. 11	38	43	1.1	4	77.8
	1	Sept. 5	Sept. 17	13	69	5.3	8	78.9
Total	3			99	227			
Average				33	75.6			
Weighted average						2.3		76.3
Maximum				48	115	5.3	8	
Minimum				13	43	1.1	4	

The total oviposition of these females was surprisingly low, ranging from 43 to 115 and averaging 75.6 eggs per female. The average number of eggs per day was only 2.3 and the maximum number of eggs in one day was only 8.

Results of the mating of male of A. grandis and female of A. g. thurberiæ.—In June two of the female *thurberiæ* received were mated on cotton squares with male *grandis* collected in the field. As these females had been shipped with *thurberiæ* males, there was a possibility of their being fertile at the time of placing with *grandis* males, but refertilization probably occurred.

These females deposited 115 and 130 eggs respectively, with an average of 122.5 each. The average per day was 3.4 and 3.9 eggs, making an average of 3.6 each for the two females. The maximum in one day was 7 eggs.

In the fall three females of *thurberiæ* reared from Thurberia bolls received from Arizona were mated with the males of *grandis* on cotton squares immediately after emergence. Thus positive crosses were secured. The activities of these females are shown in Table XIII.

TABLE XIII.—*Fecundity of positive crosses of female of thurberiæ by male of grandis.*

Total, average, etc.	Number of females.	Oviposition.			Total eggs.	Eggs per day.		Mean temperature for period.
		Started.	Ended.	Period.		Average.	Maximum.	
				Days.				°*F.*
	1	Sept. 6	Oct. 27	52	95	1.8	8	73.9
	1	Sept. 3	Oct. 2	30	146	4.8	13	77.3
	1	...do....	Oct. 8	36	102	3.0	8	80.2
Total	3			118	343			
Average				39.3	114.3			
Weighted average						2.9		76.7
Maximum				52	146	4.8	13	
Minimum				30	95	1.8	8	

Here again the total eggs deposited was quite low and the average eggs per day was likewise low. However the fecundity was quite high enough to equal many of the *grandis* females depositing at the same time; consequently there seems little reason to believe that the fecundity of *thurberiæ* is less than that of *grandis*.

Results of the mating of progeny of male of thurberiæ and female of grandis.—In the latter part of June three pairs of weevils reared from eggs deposited by doubtful crosses of male *thurberiæ* and female *grandis* were mated on cotton squares. Two pairs were placed together in one jar and allowed to continue deposition until the normal cessation. These two females deposited a total of 100 eggs and averaged 4.3 per day. The maximum number in one day was 14 eggs. The other female was allowed to continue oviposition for 18 days, and in this time she deposited a total of 143 eggs at the rate of 8 eggs per day. The maximum number for one day was 15 eggs.

Results of the mating of progeny of male of grandis and female of thurberiæ.—In July two pairs of weevils reared from eggs deposited by doubtful crosses of male *grandis* and female *thurberiæ* were mated on cotton squares. Owing to the shortage of squares these weevils were stopped after having deposited for 17 and 5 days, respectively. The first female deposited a total of 131 eggs at the rate of 7.3 per day, with a daily maximum of 15, and the second deposited 48 eggs at the rate of 9.6 per day, with a daily maximum of 14.

MAXIMUM NUMBER OF EGGS PER DAY.

The maximum number of eggs deposited in 1 day by any female was 26. A first generation *grandis* female emerging June 8 deposited this number of eggs in cotton squares July 2. The mean temperature was 81.1° F. and the mean humidity was 68 per cent for the oviposition day involved. The previous record for 1 day's deposition (20 eggs) was exceeded many times by quite a number of females.

The maximum number of eggs deposited by typical *thurberiæ* on cotton squares was 17. This number was deposited September 8 at a mean temperature of 86.4° and a mean humidity of 78 per cent for the oviposition day.

The maximum for the mating of infertile female *thurberiæ* and male *grandis* was 13 eggs. This number was deposited September 10 at a mean temperature of 81.4° and a mean humidity of 83.5 per cent for the oviposition day.

The maximum for the mating of infertile female *grandis* and male *thurberiæ* was 8 eggs. This number was deposited September 16 at a mean temperature of 76° and a mean humidity of 77.5 per cent for the oviposition day.

The maximum number for females fed only on buds and blooms of *Callirrhoë involucrata* was 3 eggs.

The maximum for females fed only on the buds and blooms of *Hibiscus syriacus* was 8 eggs.

RATE OF OVIPOSITION.

The daily rate of oviposition has already been shown in the discussion of the general fecundity of the weevils, but the rate by fractions of the oviposition period of the different females is also of interest. In the following studies the oviposition period of each female has been divided into thirds and the results tabulated accordingly. This is shown in Table XIV.

TABLE XIV.—*Rate of oviposition of the boll weevil obtained in all experiments.*

Nature of weevils.	Number of females.	Season.	Rate of oviposition.					
			First third of period.		Middle third of period.		Last third of period.	
			Total eggs.	Daily average.	Total eggs.	Daily average.	Total eggs.	Daily average.
Hibernated *grandis* females.	2	May to July	136	6.5	161	7.3	105	4.6
Once fertilized *grandis* females.	5	June to September	521	9.0	484	8.2	155	2.5
Grandis females with a complete record on copulation.	9	July to August	492	5.2	590	6.0	310	3.0
Various breeding series of *grandis*.	6	June to September	415	4.7	386	4.3	219	2.3
Pure *thurberiæ*	4	September to October.	234	5.5	130	3.1	46	1.0
Positive crosses of male *thurberiæ* and female *grandis*.	3	do	77	2.4	83	2.5	67	2.0
Doubtful crosses of male *thurberiæ* and female *grandis*.	2	May to July	142	5.6	283	9.5	189	7.2
Positive crosses of male *grandis* and female *thurberiæ*.	3	September to October.	155	4.0	127	3.2	61	1.5
Doubtful crosses of male *grandis* and female *thurberiæ*.	2	June to July	81	3.9	101	4.4	63	2.7
Total			2,253		2,345		1,215	
Average				5.2		5.4		2.9

Here it is seen that the maximum rate of oviposition in the average of all series is reached in the middle period and the minimum is in the last period. However, there are several exceptions to this in the averages of the different types of females. It is interesting to compare the results of the spring and fall series. In the former the average of the middle third is much higher than the first and the last is only slightly lower, while in the fall series there is generally a great decrease in the latter part of the period. This difference is of course due to the temperature increasing from spring to summer and decreasing in the fall.

IS THE FECUNDITY OF THE WEEVIL DECREASING?

In previous bulletins on the boll weevil this question was put, but not answered because of insufficient data. A comparison of the total number of eggs laid by weevils at Victoria and the rate per day for 1902 to 1904 with 1913 gives the following results:

In 1902 to 1904 at Victoria 132 weevils laid 11,863 eggs at the rate of 89 eggs each, or 2.8 eggs each per day with a maximum of 135 eggs per female. In 1913 at Victoria 19 weevils in various seasons laid 4,036 eggs at the rate of 212 eggs each, or 5.9 eggs each per day with a maximum of 358 eggs. In one of the fecundity series in 1913 a female *grandis* exceeded even this maximum and laid a total of 456 eggs. This evidence seems to indicate that if there has been any change in the fecundity of the species it is in the nature of an increase rather than a decrease.

OVIPOSITION PERIOD.

During the summer a total of 47 females were observed through the complete oviposition period. The results of these observations are summarized in Table XV.

TABLE XV.—*Oviposition period of the boll weevil obtained in all experiments.*

Source of weevils.	Season.	Number of females.	Maximum period.	Minimum period.	Average period.
			Days.	*Days.*	*Days.*
Once fertilized *grandis* females	June to September	5	61	19	36
Grandis females with complete record on copulation.	July to August	9	52	17	32.7
Hibernated *grandis* females	May to July	12	55	12	33.8
First generation *grandis*	June to July	1			25
Third generation *grandis*	July to September	3	67	16	47.7
Last of first generation *grandis*	August to September	1			59
Fourth generation *grandis*	do	2	44	44	44
Pure *thurberiæ*	September to October	4	34	30	32
Positive crosses of male *thurberiæ* and female *grandis*.	do	3	48	13	33
Doubtful crosses of male *thurberiæ* and female *grandis*.	May to June	2	49	27	38
Positive crosses of male *grandis* and female *thurberiæ*.	September to October	3	52	30	39.3
Doubtful crosses of male *grandis* and female *thurberiæ*.	June to July	2	38	29	33.5
Total		47			
Weighted average					35.8
Maximum			67		
Minimum				12	

Here it is seen that the period ranged from 12 to 67 days with an average of 35.8 days for all females. The number of females of the different classes is too small to permit anything like an accurate comparison of results. While the pure *thurberiæ* and the crosses containing females of this variety averaged a slightly shorter time for the period than the native *grandis*, this difference is not great enough to indicate that there is any special significance in it.

Although the 1913 records on the oviposition period did not in any case approach the maximum recorded period, the average length was almost 5 days longer than the average of all previously recorded experiments.

EXTERNAL DEPOSITION OF EGGS.

In all types of breeding series and at all times during the season females were observed to deposit eggs externally. Usually, when the eggs were deposited externally, the female was either infertile or about through ovipositing but not infrequently fertile eggs were deposited externally by females on the same day they deposited a number normally. A few observations were made of fertile females depositing eggs in empty glass tubes. Every time this happened the female would turn and immediately eat the egg. This habit of eating eggs deposited externally was observed many times and undoubtedly greatly reduced the number found.

The eggs deposited externally were found in all manner of positions on the calyx and bracts of squares, some even being found on the outside of the bracts. When covered with a moist cloth and placed on damp sand several of the eggs hatched. In one case an egg hatched within 24 hours after deposition and two others hatched within 48 hours. As eggs in squares at this time were taking 3 and 4 days to hatch it seems evident that the period for those deposited externally was shortened by the greater exposure to the heat at the time. The tissue of the squares surrounding those deposited normally probably reduces the temperature affecting the eggs.

A number of larvæ were observed after hatching from eggs deposited externally. Although several of these larvæ were very near punctures in the square not one was observed to make its way into the square. They all moved around considerably but died within about one day after hatching. In one case a larva hatched from an egg placed about half inside a puncture and died without entering the square.

Some of these larvæ were taken immediately after hatching and placed in an incision in a square. These larvæ lived and matured. One larva hatched from an egg deposited on the petal of a Hibiscus bloom was placed in an opening in a Hibiscus bud and reached pupation safely.

Many of the eggs deposited externally were not observed for hatching, so no record can be given on the percentage of these eggs that were infertile, but in one series of females that were depositing fertile eggs all eggs deposited externally were kept and records made on the number hatching. A total of 20 eggs was deposited externally in this series and, of these, 3 hatched, or only 15 per cent. From this and the general observations made during the season it seems evident that by far the greater part of the eggs deposited externally are infertile, but occasionally fertile eggs are deposited in this manner.

NUMBER OF EGGS DEPOSITED FIRST DAY OF OVIPOSITION.

The number of eggs deposited the first day of oviposition by each female in all series varied from 1 to 12 with an average of 3 eggs for the 58 females observed during the season.

For typical *grandis* the number varied from 1 to 12 with an average of 3 eggs.

For typical *thurberiæ* the number varied from 1 to 10 with an average of 3.4 eggs.

The number for the mating of infertile female *thurberiæ* and male *grandis* varied from 1 to 2 with an average of 1.6 eggs. The number for the mating of infertile female *grandis* and male *thurberiæ* varied from 1 to 4 with an average of 2 eggs.

PERIOD FROM THE DEPOSITION OF LAST EGG TO DEATH.

The period from the deposition of the last egg to the death of the female in all series varied from 10 days to death on the same day that the last egg was deposited. This death on the last day of deposition was observed 5 times during the season. The average of the 42 cases observed was 3.1 days.

For the different series of typical *grandis* this period varied from 10 days to death on the last day of deposition. The average was 3.2 days.

For typical *thurberiæ* this period varied from 3 to 7 days with an average of 5.2 days.

For the mating of female *grandis* and male *thurberiæ* the period varied from 1 to 5 days with an average of 2.4 days.

For the mating of female *thurberiæ* and male *grandis* the period varied from 3 days to death on the last day of oviposition. The average was 1.8 days.

CESSATION OF OVIPOSITION BY HIBERNATED WEEVILS.

In connection with the discussion of early or late planting to escape the attack of the weevil it is interesting to note the time of cessation of oviposition by early hibernated weevils. The accompanying table (Table XVI) shows the date of the last egg deposited by each of the first twelve hibernated females collected in the spring. Here it is seen that the last egg ranged from May 29 to July 22.

TABLE XVI.—*Dates of cessation of oviposition of first hibernated females of the boll weevil.*

Date collected.	Date stopped ovipositing.	Date collected.	Date stopped ovipositing.
May 8	May 29	May 20	July 12
Do	June 4	Do	July 22
Do	June 19	Do	July 8
Do	June 22	Do	Do.
Do	July 10	May 10	June 14
May 20	June 14	Earliest date stopped	May 29
Do	June 15	Latest date stopped	July 22

DEPENDENCE OF REPRODUCTION UPON FOOD.

The studies of the feeding habits of the weevils in relation to malvaceous plants other than cotton and Thurberia have served to throw some further light on this subject. Many weevils were kept on cotton leaves only from emergence to death, but only one pair was observed in copula and not a single egg was found; but shortly after such females were transferred to squares or bolls they would start ovipositing more or less normally. The possibility of the shape of the square or boll being a mechanical stimulus to oviposition was considered for some time, but later in the season this idea was discarded. A female which had been fed only on the blooms of *Hibiscus syriacus* from emergence deposited a fertile egg on an open petal of a bloom. Then shortly after this several females were observed to oviposit in empty glass tubes. So it seems that oviposition is simply a question of food and fertility, although the element or elements needed for sexual maturity are not limited to cotton squares and bolls. This element is evidently not present in cotton foliage in sufficient quantities, but is present in varying amounts in cotton squares, bolls, and blooms, *Hibiscus syriacus* blooms, and also blooms of *Callirrhoë involucrata* and *C. pedata*.

DEVELOPMENT.

Only a few observations were made on the individual stages of development, although much work was done upon the whole period of development. The length of the stages was obtained by repeated examinations to learn the dates of transformation.

Incubation period.—The data on the egg stage are summarized in Table XVII.

TABLE XVII.—*Incubation period of the boll weevil.*

Date of oviposition.	Number of individuals.	Egg days.	Period.			Mean temperature.
			Minimum.	Maximum.	Average.	
Deposited normally:			*Days.*	*Days.*	*Days.*	° *F*
Aug. 23	9	18	2	2	2.0	88.5
24	8	17.6	2	3	2.2	87.6
28	20	53.8	2	3	2.69	86.8
29	17	48.28	2	4	2.84	86.1
Sept. 19	11	55.0	5	5	5.0	74.1
19	23	131.1	5	6	5.7	73.1
20	24	139.2	5	6	5.8	71.9
21	9	50.4	5	6	5.6	70.9
22	17	81.6	3.5	5.5	4.8	72.9
Total and average	138	594.9	2	6	4.3	.....
Deposited externally:						
May 20	1	1	1	1	1	77.4
Aug. 20	2	4	2	2	2	86.4
Total and average	3	5	1	2	1.6	.....

By this table it is noted that normally deposited eggs developed in 2 days at 88.5° and in 5.8 days at 71.9°, while eggs deposited externally and therefore directly exposed to the changes of air temperature developed in 1 day at 77.4° and in 2 days at 86.4°.

One weevil fed on flowers of *Hibiscus syriacus* deposited an egg externally on September 21. This egg hatched in 4 days at a mean temperature of 71.1°.

Larval period.—Only 26 larvæ were observed through this stage and they averaged 6 days with a minimum of 5.1 days and a maximum of 7.1 days at a mean temperature of 84.7°. One greatly retarded individual not observed to pupation required over 10 days for the period.

Pupal period.—Only 7 observations of the pupal period were made. The average period was 4.63 days, with a minimum of 4.38 days and a maximum of 5.38 days, at a mean temperature of 83.6°.

TOTAL DEVELOPMENTAL PERIOD.

The data for the total developmental period are presented in Table XVIII. Records of the development of 1,513 individuals indicate a very slightly shorter period for the females than the males. These various records are not strictly comparable until correlated with the climatic records.

TABLE XVIII.—*Data on the developmental period of the boll weevil.*

TEXAS WEEVILS.

Nature of weevils.	Larval food.	Period of oviposition.	Males.			Females.			Total number bred.	Total weevil days.	Average period.
			Number bred.	Weevil days.	Average period.	Number bred.	Weevil days.	Average period.			
					Days.			*Days.*			*Days.*
First generation...	Cotton squares.	May 19–31.....	54	884	16.3	50	804	16.0	104	1,688	16.2
Do.....	...do....	June 1–5.....	72	1,206	16.7	75	1,249	16.6	147	2,455	16.7
Do.....	...do....	June 6–10.....	57	895	15.7	44	700	15.9	101	1,595	15.7
Do.....	...do....	June 11–15.....	48	729	15.1	33	493	14.9	81	1,222	15.0
Do.....	...do....	June 16–20.....	27	379	14.0	34	470	13.8	61	849	13.9
Do.....	...do....	June 21–25.....	36	477	13.2	40	526	13.1	76	1,003	13.1
Do.....	...do....	June 26–30.....	33	447	13.5	32	418	13.0	65	865	13.3
Do.....	...do....	July 1–16.....	12	176	14.6	13	184	14.1	25	360	14.4
Second generation.	...do....	June 17–30.....	41	552	13.4	42	562	13.3	83	1,114	13.4
Offspring single pair.	...do....	June 25–July 12.	13	178	13.7	10	134	13.4	23	312	13.5
Second generation.	...do....	Aug. 19–Sept. 26.	8	128	16.0	5	81	16.2	13	209	16.0
Third generation..	...do....	July 7–10.....	3	39	13.0	5	68	13.6	8	107	13.3
Fourth generation.	...do....	July 27–30.....	4	52	13.0	4	56	14.0	8	108	13.5
Fifth generation...	...do....	Aug. 20–Sept. 9..	8	133	16.6	5	72	14.4	13	205	15.7
Sixth generation...	...do....	Sept. 9–17.....	3	56	18.6	3	57	19.0	6	113	18.8
Do.....	...do....	Oct. 3.....	....	.....	.....	1	21	21.0	1	21	21.0
Seventh generation	...do....	Oct. 11–14.....	2	43	21.5	1	21	21.0	3	64	21.3
Miscellaneous series	...do....	July 3–Aug. 2...	118	1,544	13.1	91	1,170	12.8	209	2,714	13.0
True *grandis*.	...do....	May–Oct.....	539	7,928	14.7	488	7,086	14.5	1,027	15,014	14.6

TABLE XVIII.—*Data on the developmental period of the boll weevil*—Continued.

ARIZONA WEEVILS.

Nature of weevils.	Larval food.	Period of oviposition.	Males.			Females.			Total number bred.	Total weevil days.	Average period.
			Number bred.	Weevil days.	Average period.	Number bred.	Weevil days.	Average period.			
					Days.			Days.			Days.
First generation	Cotton squares.	Sept. 2–24	20	353	17.6	12	207	17.2	32	560	17.5
Do	...do	May 27	2	38	19.0	....	.....	.....	2	38	19.0
Do	...do	Sept. 20	1	18	18.0	....	.....	.....	1	18	18.0
Do	...do	Sept. 3–10	3	55	18.3	2	37	18.5	5	92	18.4
Do	Cotton bolls.	Sept. 12–15	2	49	24.5	3	76	25.3	5	125	25.0
True *thurberiæ*.	Cotton forms.	May, Sept.	28	513	18.3	17	320	18.8	45	833	18.5
Male *grandis* by female *thurberiæ*:											
First generation.	Cotton squares.	Sept. 7–Oct. 2	11	218	19.8	13	228	17.5	24	446	18.5
Do	...do	June 6–July 3	20	270	13.5	19	257	13.5	39	527	13.5
Second generation.	...do	July 2–15	15	212	14.1	11	157	14.2	26	369	14.1
Total	.....	.....	46	700	15.2	43	642	14.9	89	1,342	15.0
Male *thurberiæ* by female *grandis*:											
First generation.	Cotton squares.	Sept. 5–Oct. 4	22	387	17.5	15	265	17.6	37	652	17.6
Do	...do	May 30–June 15	83	1,415	17.0	73	1,049	14.3	156	2,464	15.7
Do	...do	June 16–30	35	453	12.9	39	510	13.0	74	936	13.0
Do	...do	July 1–7	17	208	12.2	18	226	12.5	35	434	12.4
Second generation.	...do	June 24–July 6	21	293	13.9	29	389	13.4	50	682	13.6
Total	.....	.....	178	2,756	15.4	174	2,439	14.0	352	5,195	14.7
Total of all varieties.	.....	1913	791	11,897	15.0	722	10,487	14.5	1,513	22,384	14.7

The total developmental period was also tested in the buds of *Hibiscus syriacus* during September and October. Three *thurberiæ* varied from 15 to 17 days, with an average of 16 days, and 2 *grandis* gave a period of 17 and 18 days, or an average of 17.5 days.

GENERATIONS.

In order to determine definitely the possible number of generations of weevils in one season two series were carried through the breeding season. These were to determine the maximum and minimum number of generations in cotton squares from the first hibernated females to emerge in the spring.

In the maximum series the first eggs from the first hibernated females found were saved for the emergence of the adults. The first of these adults to emerge were mated, their first eggs saved, and so on through each generation. Table XIX shows the results of this series.

TABLE XIX.—*Number of generations of the boll weevil—maximum series on squares.*

[First generation from first eggs of females that emerged from hibernation May 8 to 10.]

Generation.	Date.	Mean temperature for period.[1]	Period from maturity to maturity (about).
		° *F*	*Days.*
First generation:			
Eggs laid	May 19–24		
Generation mature	June 4– 8	78.2	28
Second generation:			
Eggs laid	June 17–22		
Generation mature	July 1– 4	80.1	26
Third generation:			
Eggs laid	July 7–10		
Generation mature	July 20–22	84.3	19
Fourth generation:			
Eggs laid	July 27–30		
Generation mature	Aug. 9–11	87.5	20
Fifth generation:			
Eggs laid	Aug. 19–22		
Generation mature	Sept. 3– 5	85.2	25
Sixth generation:			
Eggs laid	Sept. 8–10		
Generation mature	Sept. 27–29	76.5	24
Seventh generation:			
Eggs laid	Oct. 7–11		
Generation mature	Nov. 2– 4	69.8	36

[1] The period referred to here is that from the average time of emergence of a generation to the same time in the next generation.

The weevils were very unusually late in emerging from hibernation at Victoria in the spring of 1913, the first being found on May 8. This is at least two or three weeks later than the usual time. As a result, nearly one complete generation was cut off the first of the season. The last generation secured in the breeding series was the seventh. The adults of this generation emerged November 2 to 4. At this time the cool weather had practically stopped all breeding in both cages and field, and this was considered to be the last generation. However, the weather became warmer in the latter part of November and December, and on the 26th of December Mr. J. D. Mitchell found breeding in progress in the field. This was evidently a case of an extra generation caused by the unusually warm weather after the starting of hibernation. The maximum number of generations in squares at Victoria in a normal season is evidently seven or eight.

The minimum generation series was conducted quite differently. The last eggs were secured from the hibernated females used in starting the maximum series. The last adults reared from these eggs were mated and their last eggs secured. The results of this series are shown in Table XX. The last adults of the second generation did not mature until October 13 to 15, and as these certainly would enter hibernation this was considered as the minimum number of generations from the first hibernated females. As the last females to emerge from hibernation in the spring would continue ovipositing much longer and the last weevils of the first reared generation would mature much later in the season, it seems quite possible for weevils of the first generation to enter hibernation in the fall.

TABLE XX.—*Number of generations of the boll weevil—minimum series on squares.*

[First generation from last eggs of females that emerged from hibernation May 8 to 10.]

Generation.	Date.	Period from maturity to maturity (about).	Mean temperature for period.
		Days.	*° F.*
First generation:			
Last eggs laid	July 14–16		
Generation mature	July 29–30	81	80.7
Last generation:			
Last eggs laid	Sept. 26–30		
Generation mature	Oct. 13–15	78	80.7

HIBERNATION.

The hibernation of variety *thurberiæ* in bolls of Thurberia is longer than any other phase of this phenomenon for the species. The adults mature in their cells before December, but remain therein until August or later around Tucson, Ariz. When removed from the cells they begin activity immediately.

NATURAL CONTROL.

Parasitism.—The parasitism of native weevil stages at Victoria during the season was very slight. In spite of the large numbers of infested squares and bolls collected in the field and held for the emergence of weevils, not a single parasite was reared. Several hundred infested squares and bolls were opened during the season and only one parasite larva was found.

Late in the season two lots of squares were sent to the writer from Tallulah, La., by Mr. G. D. Smith. These were placed in cages for the emergence of adults and five species of parasites emerged. These were: *Bracon mellitor* Say; *Catolaccus incertus* Ashm.; *Catolaccus hunteri* Cwfd.; *Cerambycobius cyaniceps* Ashm.; *Eurytoma tylodermatis* Ashm. Of these Bracon was much the more abundant.

From the *thurberiæ* imported from Arizona only one parasite was reared at Victoria. This was a specimen of *Eurytoma* sp. which had parasitized a weevil larva.

During September what threatened to be a serious outbreak of a mite (probably *Pediculoides* sp.) appeared in the various breeding series. This infestation spread rapidly over many of the shelves where immature stages of weevils were being reared and soon killed a considerable number of these. This infestation was evidently controlled by the cool weather and no further trouble was experienced.

Messrs. Schwarz and Barber found in Thurberia bolls two individuals parasitized by Ichneumonoidea.

Disease.—During the latter part of the season a curious epidemic of deaths of newly emerged weevils occurred in one breeding series.

Little attention was paid to the deaths at first, but in about three days nearly all weevils in this series had died. It was then noted that instead of presenting the usual appearance of death the weevils became very dark in color, almost black, in fact. On touching these weevils it was found that they were very soft and the body contents were liquified. This liquid had the usual dark color and characteristic odor of flacherie of lepidopterous larvæ. The source of the seemingly diseased weevils was investigated, and it was found that all came from squares kept in a California breeding box which had contained lepidopterous larvæ infected with flacherie only a short time previously. Two of the dead weevils were submitted to Dr. G. F. White, of this bureau, for bacteriological examination, and he reported as follows:

> In the examinations made the findings in the two specimens are the same. The direct examination shows the presence of a very large number of microorganisms, which seem to be bacteria. The appearances suggest that most of these organisms belong to one species. Comparatively few colonies appeared in plate cultures made from the material. There is some indication, therefore, that the trouble is bacterial in origin. These results can be interpreted, of course, only as suggesting the possibility.

While the results secured by Dr. White are by no means conclusive, they do, as he says, suggest the possibility of a bacterial disease of the boll weevil. Although it is but a mere possibility, there is evidently an opportunity for considerable profitable investigation of the subject.

BEHAVIOR OF LOUISIANA WEEVILS AT VICTORIA.

Late in the season a number of infested squares were imported from Tallulah, La., in order to test the weevils emerging from them in their various life functions in comparison with Texas weevils. As the work was interrupted by the cool weather very little was learned from the series, but some results of interest were secured. Four pairs of weevils were mated on cotton squares immediately after emergence and tested for fecundity. These weevils emerged on September 18 and on September 20 one female deposited 1 egg and another deposited 2. The latter female deposited another egg on September 22, and then neither of these two deposited any more eggs before the series was closed on October 29. The third female lived through the same period and did not deposit an egg. The fourth female emerged September 20, deposited 1 egg on September 22, and then waited 14 days before depositing another. Then deposition started normally and 37 eggs were laid in the next 23 days. These results are very peculiar, especially the fact that three out of the four females began deposition on the second day after emergence and then stopped; two of them permanently and one for a period of 14 days.

The eggs deposited were tested for the maturing of adults, but none emerged, possibly owing to the cold weather. Native weevils were maturing in small numbers under the same conditions at this time, but as the number tested was so small there may not be any significance in this fact.

These weevils were also tested for their ability to subsist on a diet of *Hibiscus syriacus*. The detailed results of this test have been published in the paper on the feeding habits of the weevils. As only blooms were available no tests were made of the ability of these weevils to breed in the buds of this plant, but they seemed as well adapted to the plant as the native and Thurberia weevils.

DEVELOPMENT OF THURBERIA THESPESIOIDES.

On May 21 a supply of seeds of Thurberia from the Santa Rita Mountains, Ariz., were planted at Victoria. A bed of rather sandy soil was selected in a well-drained situation. On May 26 the first seedling appeared above the ground and 11 plants were visible by June 1. Although over 100 seeds were planted only these 11 sprouted.

These plants grew rather rapidly for a couple of months but formed no lateral branches of any consequence. The growth was entirely upward and the stems were very thin, causing the plants to require staking to prevent drooping. About August 20 a number of fruiting branches appeared near the top of the plants and these developed very rapidly. At this time the larger plants were 3½ feet in height. On August 26 the first bud was observed and many more appeared daily for a period of about three weeks. Then fruiting was discontinued for a couple of weeks followed by the production of more fruiting branches. These plants continued to grow with intermittent formation of buds until the observations were discontinued on November 6. At this time several of the plants were more than 4 feet in height.

At Batesburg, S. C., Mr. E. A. McGregor planted about 100 of these seeds in a sandy bed. Not a single one of these appeared above the soil.

At Tallulah, La., Mr. G. D. Smith planted a number of seeds and only one sprouted. This plant lived through the season.

EXAMINATION OF THURBERIA BOLLS.

On March 10, 1914, the writer examined part of a lot of infested Thurberia bolls which had been collected by Messrs. Schwarz and Barber at from 4,500 to 5,000 feet altitude in Stone Cabin Canyon, Santa Rita Mountains, Ariz., on December 6, 1913. These bolls were shipped to Washington shortly after collection and placed in a cool cellar there until the day of examination. Seventy-seven of

the bolls yielded a total of 84 live weevils; one containing 3, 5 others containing 2 each, and the remainder containing 1 each. One boll had been completely eaten out by a bollworm, and another showed signs of weevil injury and a braconid parasite cocoon. Two dead pupæ and 2 dead larvæ were found in 4 other bolls. Their deaths were in all probability due to climatic causes. The remaining boll contained signs of weevil larval work, but no insects, either dead or alive, were found. One boll which contained a weevil adult also contained a tiny, light-green lepidopterous larva.

Of the 84 weevils found in the bolls, 52 were males and 32 were females. One additional male was found crawling among the bolls when the bag was opened. Those in the bolls were all tightly sealed in the pupal cells and were usually quiet when first opened. As soon as the weevils were exposed to the air they became quite active and remained that way.

The peculiar feeding habit of the larvæ of these weevils is certainly well adapted to destroying the maximum number of seeds in a boll. They do practically all their feeding in the center of the boll and form the pupal cells in this same place. Owing to the arrangement of the seeds this location of the larva enables it to injure practically every seed in the boll instead of injuring those of one lock as is usual with the cotton weevils.

On March 12, 1914, another lot of infested Thurberia bolls were examined. These were collected by Mr. Schwarz in a small canyon between Stone Cabin and Sawmill Canyons, Santa Rita Mountains, Ariz., on December 7, 1913, at about 3,900 feet altitude. The bolls were sent to Washington soon after collection and had been in a cool cellar from that time until examined.

Examination of 39 of the bolls showed 2 clean and the remainder infested. Thirty-three bolls yielded 36 live weevils, 3 bolls containing 2 each. Three dead adults (2 females and 1 male) were found in as many bolls. These deaths were probably due to climatic causes. One boll was found which showed signs of larval injury but the larva was not to be found. No signs of parasitism were found. One lepidopterous larva like the one noted in the preceding lot was found in a boll with a weevil. The live weevils consisted of 18 males and 18 females.

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No. 233

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
May 27, 1915.

RELATION OF THE ARIZONA WILD COTTON WEEVIL TO COTTON PLANTING IN THE ARID WEST.[1]

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INTRODUCTION.

With the introduction of cotton culture into Arizona under conditions of irrigation, it was hoped that the establishment of important insect pests could be prevented by quarantines, and this was rendered possible by the complete isolation of the new territory. Recent investigations in Arizona, however, have revealed the presence of a weevil, *Anthonomus grandis thurberiæ*, very nearly identical with the famous Mexican cotton-boll weevil which has proved so disastrous to cotton culture in many parts of the South. This is due to the occurrence, in many of the mountain ranges of the southeastern section of the State, of a wild cotton plant known technically as *Thurberia thespesioides*. This plant, which is so closely related to cotton that some investigators have classed it in the genus Gossypium (the genus of cotton), was found to be the host of a weevil closely related to the cotton-boll weevil, as well as the host of a number of other insects, and it was at once perceived that there was a possibility that these insects might attack cultivated cotton grown near these mountains. Of the various insects found on the wild cotton plant, the weevil is probably the most important, and the present bulletin deals with this species.

HISTORY OF THE WEEVIL.

While the history of the cotton-boll weevil is a familiar subject to almost every one in the infested territory, it is not nearly so well known in the western cotton country, and a brief review of its activities in the United States will help to an understanding of the significance of its presence in Arizona.

The Mexican cotton-boll weevil, *Anthonomus grandis* Boh., came into the United States from Mexico, crossing the Rio Grande at

[1] The investigations on which this paper is based were conducted under the direction of Mr. W. D. Hunter.

Brownsville, Tex., about 1892. Since that time it has advanced steadily northward and eastward until at the present time it is in Texas, Louisiana, Oklahoma, Arkansas, Mississippi, Alabama, and Florida, and the total area infested in 1914 was 312,300 square miles. Estimates made by the Bureau of the Census place the total loss in production of cotton lint in the United States due to the ravages of this species at 10,000,000 bales, or a money loss of $500,000,000. Thus we see the importance of this little beetle of insignificant appearance in the area now infested.

Extended studies have been made by the Department of Agriculture and also by the various State offices in the attempt to reduce the damage done by the species. It has proven one of the most difficult insects to combat, owing largely to its habit of feeding at all times on inner plant tissue and so making the use of poisons practically worthless. The most effective methods of reducing damage which have been developed are principally cultural.

During the summer and fall of 1913 the writer experimented with the Arizona wild cotton weevil and the Texas cotton weevil at Victoria, Tex., crossbreeding them and testing the adaptation of the Arizona form to conditions of cultivated cotton in the South. In April, 1914, the work was transferred to a ranch near Tucson, Ariz., and was continued until the middle of November. This bulletin is a partial result of these studies.

Although the Thurberia plant has been studied botanically for some years, owing to its close relation to cotton, economic interest from an entomological standpoint was first aroused early in 1913, when Mr. O. F. Cook, of the Department of Agriculture, announced the discovery of the weevil breeding in the bolls of this plant in Arizona. This announcement was at once followed by a study of the exact taxonomic status of the weevil, its distribution, habits, and probable economic importance. It was soon found to be not identical with the cotton-boll weevil of the South, but so closely related that the two forms would interbreed readily. It was then described as a variety of *Anthonomus grandis* by Mr. W. Dwight Pierce, of this bureau, and given the varietal name *thurberiæ*. Further investigations lead to the belief that the two types are geographical and environmental varieties arising from a common ancestral form which was probably native to some point in southern or central Mexico. The two forms have probably spread northward along separate lines of distribution in the course of time and have acquired slight differences in structure and habit.

These differences in structure of the adult beetles are so slight that they are not apparent to the untrained eye and the descriptions used in this paper are applicable to either type.

DISTRIBUTION.

The discovery that the weevil breeds on Thurberia furnished the first intimation that it lives on any plant other than those of the genus Gossypium, though the writer has since demonstrated that it is able to develop on some other closely related malvaceous plants. However, it is not likely that this occurs in nature under normal conditions, and there is no reason for believing that the weevil feeds upon any plant other than Thurberia in the mountains. Consequently a study of the distribution and habitat of Thurberia is second in importance only to that of the weevil itself. While our knowledge of this point is by no means complete, considerable information has been gathered in the course of a number of explorational expeditions, and we possess a fair general idea of the conditions.

In Arizona Thurberia is known to occur in the Santa Catalina, Santa Rita, Tanque Verde, Rincon, Mule Pass, Huachuca, Chiricahua, Superstition, Bradshaw, Dos Cabezos, and Dragoon Mountains; at Globe, and in Fish Creek Canyon of the Salt River Valley. In Mexico it has been recorded from Guadalajara, southwestern Chihuahua, and a number of localities in eastern Sonora. The weevils have been found only in the Santa Catalina, Rincon, Santa Rita, Tanque Verde, and Dos Cabezos Mountains. Of these ranges the first four adjoin the Santa Cruz Valley, in which Tucson is located, and the last is near Bowie. From these data it is seen that the plant is rather generally distributed throughout the southeastern part of Arizona and that the weevil infestation, so far as is known at present, is more or less concentrated around Tucson. Of course, additional explorational work will undoubtedly disclose new localities where both plant and weevil are present.

Because of the apparent concentration of the weevils around Tucson it was believed that this was the point of greatest danger of infestation of the cultivated cotton, and the economic investigations were conducted there. While the largest area of cotton cultivation in the State is in the Salt River Valley in the vicinity of Phoenix, the weevil has not been found near there, and the Santa Cruz Valley seemed in more immediate danger.

THE THURBERIA PLANT.

Many of the habits of the weevil are directly dependent upon the characteristics of the Thurberia plant, and the habitat and activities of this plant have been carefully observed. It is found at altitudes ranging from a little over 2,000 feet to 7,000 feet. While colonies are frequently found high on the sides of the canyons and on the ridges, the most common habitat in the mountains around Tucson is in the beds of the canyons and small washes. Here it grows among the

rocks and on the small islands in the bed of the wash wherever there is sufficient moisture and enough protection from the force of the current in flood seasons. (Pl. I, fig. 1.) Many of the small washes down near the base of the mountains, not large enough to deserve the title of canyon, support great numbers of the plants. Following down from such situations the plant is found in the arroyos extending out through the mesa and often at quite a distance from the mountain range proper. (Pl. I, fig. 2.) The economic significance of this lower distribution will be discussed later in the present paper. In the ranges where the weevils have been found their distribution is very nearly as wide as that of the plant.

The Thurberia plant is a large, woody perennial and frequently reaches a height of over 10 feet, though the plants ordinarily met are from 4 to 6 feet tall. (Pl. II.) The stem is very tough after the first year's growth and supports an abundance of wide-spreading branches. The close relationship of the plant to cotton is quite apparent, and particularly so during the flowering period. A great number of buds (corresponding to the "square" of cotton) are produced. After blooming the square forms a small boll not unlike that of cultivated cotton, varying from one-half to three-fourths of an inch in length when fully developed. When these ripen and dry they open and expose the three to five cells, each containing a double row of angular, blackish seeds covered with a fine pubescence. More or less fiber resembling that of cotton is present in nearly every boll. It is in this boll that the weevil breeds.

The flowering season of Thurberia depends upon the location, moisture, altitude, and various other conditions. In practically all localities in the mountains around Tucson the leaves appear in April or May. In the lower, moist spots the plants bear fruit buds almost immediately and many fruit prolifically at this time. After two or three weeks of this flowering the buds cease to appear and there is a quiescent period during which the fruit ripens. Then another crop of buds appears and the same course is repeated. In this manner as many as four crops have been noted on a few plants during the season of 1914 and many bore three. This condition was found only at altitudes below 3,000 feet. Many plants midway up the mountains bore a partial crop in July and then had a heavy one in August and September, while others at much the same altitude had only the latter crop. Throughout the entire upper distribution (above 4,500 feet) the plants grew luxuriantly all summer, but not a single fruiting bud was produced until August. Then an enormous crop appeared, and flowering continued until the latter part of September. This flowering evidently varies in the same situations in the different seasons according to the amount of rainfall.

FIG. 1.—HABITAT OF THE WILD COTTON WEEVIL AND ITS HOST PLANT.

Basin of the Milagroso Canyon in the Santa Catalina Mountains, Ariz. This is an ideal location for *Thurberia thespesioides*, the wild host plant of *Anthonomus grandis* var. *thurberiæ*. Two large plants may be seen near the right-hand margin of the photograph. (Original.)

FIG. 2.—THE WILD COTTON WEEVIL AND ITS HOST PLANT IN THE LOWER RANGES.

Habitat of *Thurberia thespesioides* and the wild cotton weevil in the lower ranges. This view was taken in the Agua Caliente Arroyo, Ariz., about 100 yards below the plant shown in Plate II, figure 1. (Original.)

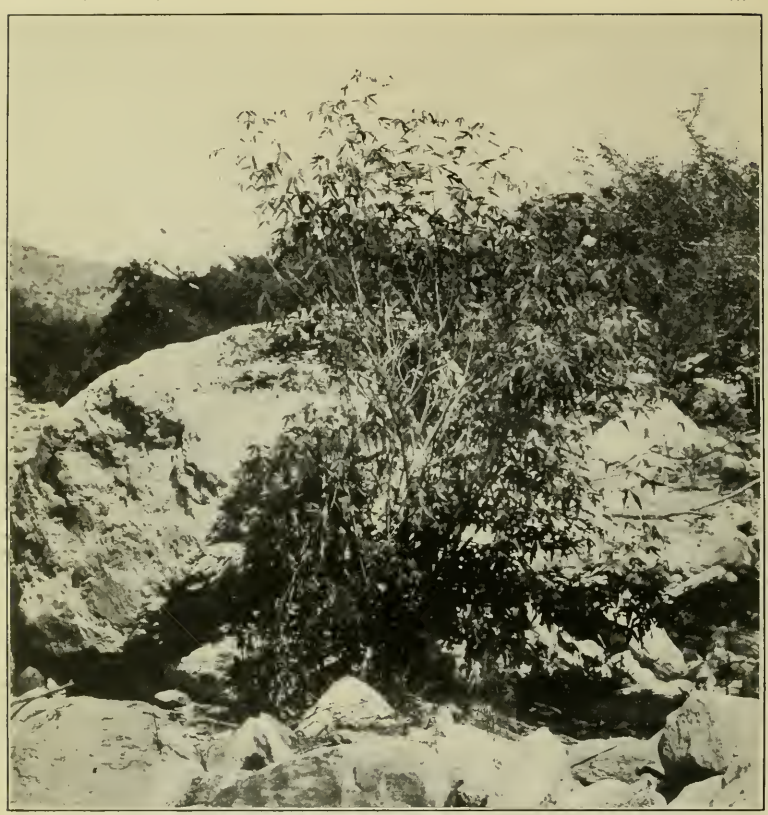


FIG. 1.—DISPERSION OF THE WILD COTTON WEEVIL.

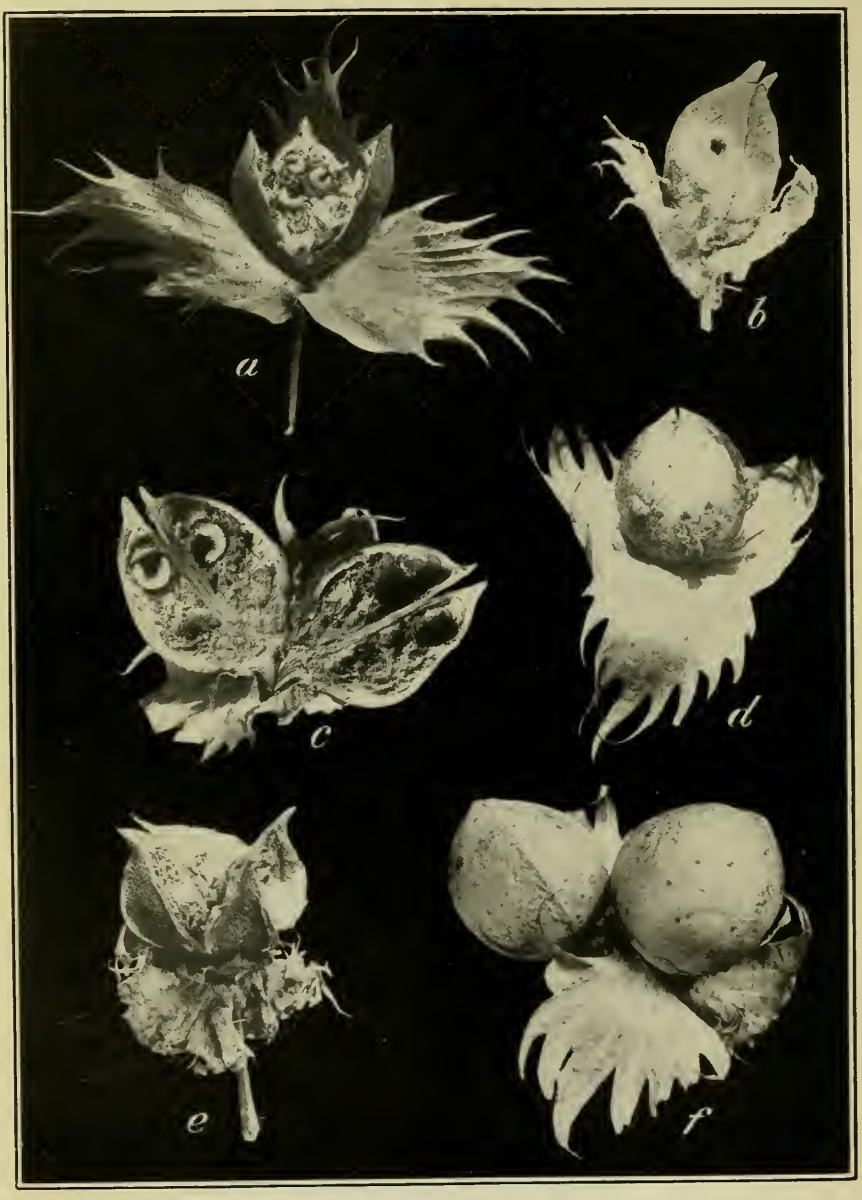
Typical location of Thurberia plant, below rock, in Agua Caliente Arroyo, Ariz., about 1½ miles from the mouth of the canyon. (Original.)

FIG. 2.—THURBERIA THESPESIOIDES, HOST PLANT OF THE WILD COTTON WEEVIL.

Growth of Thurberia at Agua Caliente Ranch, Ariz., under cultivated conditions. This is one season's growth from seed. (Original.)

INJURY BY BOLL WEEVIL TO SQUARES.

a, Bloom checked by attacks of larva; *b*, square opened, showing grown larva; *c*, square opened, showing pupa; *d*, dwarfed boll opened, showing one larva and two pupæ; *e*, weevil escaping from square; *f*, emergence hole of adult in square. (From Hunter and Pierce.)



INJURY BY BOLL WEEVIL TO BOLLS.

a, Three larvæ in boll; *b*, emergence hole in dry unopened boll; *c*, two larvæ in boll; *d*, weevils puncturing boll; *e*, opened boll, with two locks injured by weevil; *f*, large bolls severely punctured. (From Hunter and Pierce.)

LIFE HISTORY OF THE WEEVIL ON COTTON IN THE SOUTH.

In order to understand the life cycle of the weevil it is well to review briefly its action on cultivated cotton in the Southern States. The female bores a small cavity in the square or boll and deposits the egg in this, sealing the opening with a small gelatinous scale. The egg hatches in a few days and the larva or "worm" feeds upon the inner plant tissue. (Pls. III and IV.) After a period varying from a few days to about two weeks the larva transforms to the pupa, a quiescent stage in which the first resemblance to the adult weevil is shown. After a few days in this stage the pupa sheds its skin and becomes the adult weevil, which quickly leaves the square or boll in which the immature stages were passed and is soon ready to start the cycle again. These immature stages usually require from two to three weeks, although they vary with the temperature, food, and other environmental factors. Starting in May or June and continuing until September or October, as is the case in the cotton States, it is quite possible for six or eight generations to be produced in a single season, and as most females deposit from 100 to 300 eggs or more the progeny of a single pair may reach enormous numbers in the course of a season. In fact, it has been conservatively estimated that the annual progeny of a single pair of hibernated weevils would reach 3,089,520.

LIFE HISTORY OF THE WEEVIL ON THURBERIA.

While the details of the life cycle of the Thurberia weevil in the mountains in Arizona are much the same as those of the cotton weevil in the South, there are a number of important differences. Among them is the mode of hibernation, or manner in which the winter is passed.

Adults of the last fall generation of the cotton weevil usually emerge from the squares or bolls in which they breed and seek shelter in all kinds of situations offering protection near the cotton fields. A great variety of crevices, trash, moss, and other shelters are used for this purpose. The Thurberia weevil, on the other hand, fails to emerge in the fall, but remains sealed up in a cell formed in the midst of the seeds in the boll and passes the winter in this condition. Then in the spring, instead of becoming active with the first warm weather, as the cotton weevil does, the greater number of them remain sealed in the cell until the rains late in the summer, many not emerging until August. This is simply a case of prolonging the period of hibernation into one of aestivation, a habit often observed among species living in arid regions. In order to know when to expect the weevils, a number of experiments have been conducted in the laboratory and close observations have been made in the

field to determine just what conditions are necessary to cause the emergence of the adult. By combining the records secured under both natural and artificial conditions it seems quite possible to determine more or less definitely under what conditions the weevils emerge, and by studying the seasonal climatology of the region inhabited by the weevils we may know when to expect the appearance of the adults.

During the winter the boll containing the weevil cell passes through a continual process of partial disintegration caused by alternate moistening and drying. Following this, more or less moistening of the weevil cell is necessary to allow emergence in most cases, although an occasional individual emerges from time to time from the poorly constructed cells. With this as a basis we need but study the distribution of the rainfall through the spring and summer months in order to determine when emergence of the weevils is to be expected. The temperature is undoubtedly usually high enough by the 1st of April, and the emergence depends almost entirely upon the rainfall from this time onward. April, May, and June are the dry months in this locality, but a study of the seasonal precipitation for a number of years shows that even in the driest of years there are some few light rains in this period and usually some precipitation each month. So we may expect a scattering emergence of the weevil throughout the spring and summer months, the extent of this emergence depending upon the amount of the precipitation, and finally culminating in the almost complete emergence following the heavy rains of July and August.

This very late emergence of the Thurberia weevils shortens the breeding period in the greater part of the mountains to not over two generations annually instead of the six to eight of the cotton weevils.

It should be remembered that while this habit of hibernation and aestivation prevails in nature now, it is by no means certain that it will be adhered to by the weevils in case they attack cultivated cotton in the valley, but it appears likely to continue for some time at least. Weevils reared on cotton in Arizona showed a very definite adherence to this cell hibernation habit when bred in the bolls, but it seems that they will emerge from the squares. Since the females greatly prefer bolls for oviposition it seems probable that nearly all of the late-season breeding will be in these, and consequently little emergence in the fall should be expected. In case the weevil adheres to this cell hibernation habit the control should be quite simple, entailing only the winter destruction of the plants and hibernating weevils.

Most of the breeding on the Thurberia plant seems to be in the bolls, and under normal conditions the bolls from one-third to three-fourths grown are selected for egg deposition. The eggs are placed

in the punctures just as in the case of cotton weevils and the openings are sealed in the usual way. The larva feeds upon the immature seeds and develops in much the same manner and time as the cotton weevil.

DESCRIPTION OF STAGES OF THE WEEVIL.

The egg.—The egg of the weevil is usually elliptical in shape and is of a pearly white color. It is slightly less than 1 millimeter (one twenty-fifth of an inch) in length and is deposited by the female at the bottom of a small opening, usually near the base of the bud or boll, and deep among the plant tissues.

The larva.—Immediately after hatching the young larva is a white legless grub only slightly longer than the egg itself. It feeds entirely upon the inner tissue of the bud or boll and enlarges the cavity as it grows. It soon assumes a ventrally curved, crescentic form and when fully developed averages about 1 centimeter (two-fifths of an inch) in length across the curve.

The pupa.—The pupa is either pearly or creamy white and is very delicate. The form of the legs, beak, and wings may be observed in this stage.

The adult.—When the weevil first transforms from the pupa to the adult it is quite soft, weak, and very light in color. It hardens and darkens in the course of a day or two and is then fully mature. It is a stout, subovate beetle, with a long snout or proboscis. The color varies from light golden brown to very nearly black, according to the age and condition of the individual. When newly emerged it is clothed with light-colored scales, but these frequently rub off in the course of the activities of the weevil, and the darker color of the body predominates.

The size of the adult is also exceedingly variable and is determined largely by the food supply of the larva. In length adults vary from 2.5 to 7 millimeters (one-tenth to one-fourth of an inch).

NATURE OF DAMAGE TO COTTON.

The actual damage of the weevil to cultivated cotton consists in the direct attack upon both the buds and bolls. The adults feed by making punctures with their long beaks deep into the tissues of these, and several such punctures will prevent a bud from blooming or will destroy the lock of the boll in which they are located. By far the greater part of the injury, however, is due to the work of the larval or "worm" stage. The female weevil deposits the egg in the bud or boll and the one larva completely destroys the contents of the bud or lock in which it is located. Within a few days after the deposition of the egg the square "flares." That is, the involucral bracts or greenish leaves, with which the bud is normally

covered, open back flat in a very abnormal position and become pale, sickly yellow. Such an injured square is very conspicuous on a plant in the field and is usually the first indication noted of the presence of weevils. After a few days the square falls to the ground in nearly all varieties of cotton, and in heavily infested fields in the South it is a very common sight to see great numbers of these squares scattered beneath the plants. With the bolls the injury is not so easily noted, since they do not fall unless very heavily infested, but the punctures are readily found by a careful examination, and frequently the form of the boll is distorted. (Pls. III and IV.)

FOOD PREFERENCES OF THE ARIZONA WEEVILS.

A number of tests have been made to determine whether or not the Thurberia weevil displays any preference for either Thurberia or cultivated cotton. These experiments were conducted both in the laboratory and in large cages in the field, and great care was taken to eliminate all factors from the choice other than the actual attraction of the plants. It was found that individuals removed from hibernation cells and offered both plants displayed what seemed to be only the slightest choice in favor of Thurberia, and this disappeared after a few days' feeding. Weevils removed from the cells and fed only upon Thurberia for a few days and then offered a choice at first displayed a marked preference for Thurberia. After a few days' feeding in the presence of both plants this preference gradually disappeared and cotton was as much eaten as Thurberia. Weevils fed only upon cotton for a few days after removal from the cells would at first display a choice in favor of cotton, but this disappeared in the same manner. From these experiments, and also from observations made in the field in 1914, it seems safe to conclude that the weevils have very little inherent preference for either plant and that neither plant has the power to attract them away from the other.

THE TRANSFER TO COTTON.

The transfer of the weevil to cultivated cotton may be accomplished in two ways, i. e., by flight or by water. While it is of course impossible to determine the exact extent of the flight of these weevils, either in distance or frequency, all available evidence seems to indicate that this means is likely to be of little importance in the primary spread of the weevils. It seems that as long as there is an abundance of food at hand the weevils will fly very little, but in case of food shortage they fly readily. On the other hand, the habits and present distribution of the weevil make the species particularly adapted to dispersion by floods. Most of the Thurberia plants grow either directly in the wash of a canyon or arroyo or where the surface drainage is directly into such a wash. Many of the bolls containing

the hibernating weevils in their cells fall to the ground during the months of the winter, spring, and early summer, and because of their size and shape they are well adapted for being carried great distances out through the foothills on to the plains by the floods that occur every season. Here they are deposited by the water, and, the cells having been sufficiently moistened, the weevils emerge. Thence they will fly in search of food, and if they have been carried out into the zone of cotton the danger of infestation is quite apparent. It is in this manner that the infestation is most likely to take place; hence the importance of a study of the surface drainage carrying the water from the infested mountains into the various rivers.

In this connection the distribution of the plants through the lower arroyos is especially important. In many localities these now support weevils and so are a constant menace to cotton, while even where the weevils are not now present they are always likely to serve as stepping stones in the downward movement of the weevil maintained by the floods.

In the course of the investigations several small plats of cotton were planted, comprising in all a little over one-fourth of an acre. On the 30th of July the writer noted several flared squares in this cotton. Examination showed them to contain weevil punctures, and a careful survey of the entire plat revealed the fact that a light infestation of weevils was present. During the remainder of the season all infested squares and bolls noted were collected and a few adult weevils were captured on the cotton. The infestation never became heavy, but it was quite evident that some 10 or 15 weevils arrived at the plat at different times during the next two months. This is of course conclusive proof of the transfer from wild to cultivated cotton.

Early in the season, when a survey of the countryside was made, it was decided that the ranch where this cotton was planted was a logical point for infestation by the boll weevil. It is located at the junction of the arroyos from two large canyons, and consequently receives a concentration of the water flow from these two canyons and all intermediate territory. The Thurberia plant is quite common throughout this drainage system and extends down to within a fourth of a mile of the ranch, although the nearest plants found infested with weevils are slightly farther away. The writer feels that in the course of the weevil collections during the early summer every weevil within at least a mile of the ranch was gathered; the infestation must therefore have been due to weevils brought down by the floods from some distance above. In fact the week before the infestation was first noted there had been a number of rains in this territory, and on one occasion the canyons had poured water down into the washes and out as far as the ranch. These arroyos are nearly

all very rapid in descent near the mountains, and very rocky, so that comparatively little of the water seeps into the ground in this part of the journey and the force of the current scours the channel clean. Just above the ranch the character of the stream bed changes and it becomes wide and sandy. Here the water seeps rapidly and practically every flood of the present season was able to reach but little below the ranch in this sand. Hence the Thurberia bolls containing weevils may be expected to pass through the rapid part of the stream and be deposited on the sand where the flow stops near the ranch. It was probably some such procedure as this which caused the infestation of the experimental cotton during the season of 1914, and the possibility of future infestation will always be present.

PROSPECTS.

From the various observations reported herein it seems quite evident that it is only a matter of time until the weevil will appear on the cotton cultivated near Tucson. The territory best adapted for the cultivation of cotton and that upon which it seems most likely to be raised is nearly all within easy reach of the floods from weevil-infested territory. While it is obviously impossible to state that the infestation will appear at a certain point, there are many places more liable to infestation than others. Such a location has been described at the ranch where the cotton was infested and a number of similar ones occur along the mountain slopes. The fact that the experimental cotton was infested during 1914 demonstrated the importance of such a situation, but, on the other hand, it is by no means certain that the infestation would be repeated each season. However, the movement of the weevils out into the plains which takes place every year must sooner or later result in the infestation of cultivated cotton in the valley. These weevils which are washed into the field can do comparatively little damage themselves, but the result to be feared is that their progeny will become established in the valley, will winter there, and will become more and more adapted to injuring cultivated cotton.

Another point which is likely to be of prime importance in the transfer of the weevil is the practice among many ranchers of using these floods for irrigating their land. A ditch is opened from the arroyo and in time of flood the water is diverted into this ditch and conveyed to the cultivated land. Agua Caliente arroyo is tapped in this manner near one corner of the Agua Caliente ranch and the water is led off to a ranch on the west side of the stream bed. Soldier's Canyon arroyo is tapped in the same way about one-half mile from the mouth of the canyon and the water is carried off to the southwest through several homesteads. The water from Sabino and Bear Canyons is used in the same way near the junction of the two arroyos. Since these

ditches all leave the washes at points very close to Thurberia plants and in some cases among weevil-infested plants, it is quite easy to see the probable importance of this method of irrigation in introducing weevils and weevil-infested bolls directly into the fields.

It is also the custom of a number of ranchers down in the river valleys to allow their land to be flooded whenever possible in order to secure the soil deposit as well as moisture. While these places are farther from weevil sources it is quite possible for weevils to be introduced in this manner.

At present the cotton cultivated near Tucson is practically all northwest of the city near the Santa Cruz and Rillito Rivers. The nearest mountains in which we have found the weevils are the Santa Catalinas, and at the western end these drain more or less directly into the valley now cultivated. Pima Canyon and the small washes adjoining it drain slightly west of south into the Rillito and thence directly into cotton land. The northwestern slope at this end of the range, including Montrose and Romero Canyons, drains into the Canada del Oro, and this water flows southwest into very nearly the same territory. The drainage of the entire southern slope of the Catalina Range is thickly infested with the weevils, which frequently extend along the "washes" very nearly to the Rillito. There is no doubt that every season a number of weevils are washed down into this country, and any cotton cultivated in this part of the Rillito Valley will be in constant danger of infestation. On the east the Tanque Verde Mountains supply a stock of weevils carried down toward the village of Tanque Verde, while southeast of Tucson, near Vail and Irene, the headwaters of the Pantano are furnished with weevils from the ends of the Rincon and Santa Rita Ranges. South of Tucson in the valley of the Santa Cruz the drainage from the northwestern slopes of the Santa Ritas contains weevils and Thurberia plants well down toward the river itself. West of Tucson there seems to be very little danger other than that from the end of the Catalinas, as the Tucson and other ranges here seem unable to support the plant.

Under the existing circumstances there seems to be no measure which can be taken to prevent the introduction of the weevil into cotton fields, but a close watch should be continued at all times in order that an attempt may be made to control them as soon as they appear. Planters should maintain a careful watch for either flared or fallen squares and bolls in the field and examine them for either the feeding punctures or larvæ of the weevils. This observation should be especially close in fields or parts of fields adjacent to water courses carrying drainage from situations such as those described as normal for Thurberia.

At the present stage of the investigations it is impossible to predict just what the extent of the damage by the weevils will be when

they attack cotton. Many of the habits of the Thurberia weevil are adapted to the activities of these plants and to the higher altitudes at which they live, and it is questionable just how readily and to what extent it will adapt itself to cotton. But since the species has shown such great adaptiveness in the Southern States, it is to be feared that the Arizona form will do the same. At any rate, it is an ever-present menace to cotton cultivation in the Santa Cruz Valley and should be watched most carefully. It is quite probable that with a more intimate knowledge of the extent of the weevil distribution in the State it will be possible to establish local quarantines of seed-cotton shipments which will at least keep the weevils out of the localities which do not have the species present in nature. In the Southern States cotton cultivation is of course very general and there the weevil advances each season by flying, but in Arizona, where the different areas suitable for cultivation are separated by considerable stretches of mountainous country, such a means of dispersion would only be possible within very limited areas. Consequently it should be possible to keep the weevil entirely out of areas not within range of direct infestation from nature.

In addition to the watch for infestation by native weevils, the danger of importation of the weevil from the Southern States should be remembered, and all efforts should be made to validate the quarantine against this variety.

SUMMARY.

1. A weevil very closely related to the Mexican cotton-boll weevil exists on a wild cotton plant in some of the mountains of southeastern Arizona.

2. The species seems to be particularly concentrated in the ranges surrounding Tucson.

3. This weevil may transfer its attack from the wild cotton plant to the cultivated cotton in the Santa Cruz and Rillito Valleys at an early date.

4. Its present habits are such that it would not injure cotton greatly, but these habits will probably be changed to a certain extent and more injurious ones acquired.

5. The present habits render it quite probable that the control of the Arizona form will be a very different problem from that of the cotton weevil and more easily solved.

6. A careful watch should be maintained for the first appearance of the weevil on cultivated cotton in order that it may be combated successfully.

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LIV. INSECTS.

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Contribution from the Bureau of Entomology, L. O. Howard, Chief.
June 24, 1915.

CONTROL OF DRIED-FRUIT INSECTS IN CALIFORNIA.[1]

By

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INTRODUCTION.

The State of California is especially adapted to the raising of fruits. It is manifest that only a part of the great crop which is annually produced may be marketed in a fresh condition, since it is impossible to preserve semitropical and other soft fruits for more than a very limited time in the fresh state. The fruit canneries and the dried-fruit industry have accordingly been formed with a view to the utilization of the surplus fruit and have assumed large proportions, the production of dried fruits for the State of California being estimated at 140,000 carloads annually.

The importance of this industry and the fact that numerous inquiries are made concerning the control of the insects which attack dried fruits warrant investigation of the insect enemies of dried fruits in California. This was undertaken in a preliminary way in 1908, but owing to lack of funds was discontinued until 1911, at which time the writer, working under the direction of Dr. F. H. Chittenden, was assigned to this project. The investigation has been continued to the time of publication, and the preliminary notes are herewith submitted.

[1] The observations in this bulletin and the data on life history and habits were obtained in central California, the author having his headquarters at Sacramento, but it is probable that these particulars do not differ materially in other fruit-growing sections of the United States, especially in the eastern and southern fruit regions.

[2] Resigned Aug. 31, 1914.

NOTE.—The writer has been assisted in this investigation by the Roeding Fig Packing Co., the Rosenberg Co., Mr. D. L. Smith, of the Schuckl Co., the California Dried Fruit Exchange, the Robt. Gair Co., and the Petterson Carton Wrapping & Sealing Machine Co., who by their cooperation have greatly facilitated the prosecution of this project. He also wishes to acknowledge the assistance of Mr. R. E. Campbell, of the Bureau of Entomology, who brought to completion some of the experiments detailed in this paper.

INSECTS CONCERNED IN THE INJURY.

During the progress of this investigation a study of the insect forms most injurious to dried fruits in California has been pursued, with the result that the following species have been collected, the more important being considered later in separate paragraphs.

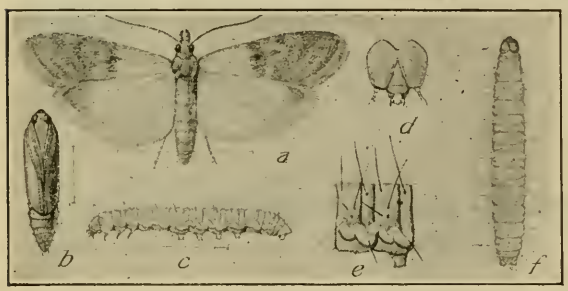


FIG. 1.—The Indian-meal moth (*Plodia interpunctella*): *a*, Moth; *b*, chrysalis; *c*, caterpillar; *d*, head of same; *e*, first abdominal segment of same; *f*, caterpillar, dorsal view. *a*, *b*, *c*, *f*, Somewhat enlarged; *d*, *e*, more enlarged. (From Chittenden.)

The Indian-meal moth (*Plodia interpunctella* Hübn.) (fig. 1) is probably the most common and destructive of these pests, its large size making it particularly conspicuous, while the nature of its attack renders infested fruit most disgusting in appearance. (See Pl. I, figs. 1, 2.) The fig moth (*Ephestia cautella* Walk.) (fig. 2) is next in importance among the moths, while a variety of beetles, including the dried-fruit beetle (*Carpophilus hemipterus* L.), the saw-toothed grain beetle (*Silvanus surinamensis* L.), the foreign grain beetle (*Cathartus advena* Waltl), and a fungus beetle (*Henoticus serratus* Gyll.), are generally injurious. Two sugar mites (*Tyroglyphus siro* Gerv. and *T. longior* Gerv.) are also frequently found. The pomace flies (*Drosophila ampelophila* Loew) attack only the sweet, watery fruits, or those that are fermenting, and can hardly be considered as dried-fruit insects. Ants are occasionally found in dried fruits, but do not breed therein, and can usually be best attacked by destroying their nests outside the packing house.

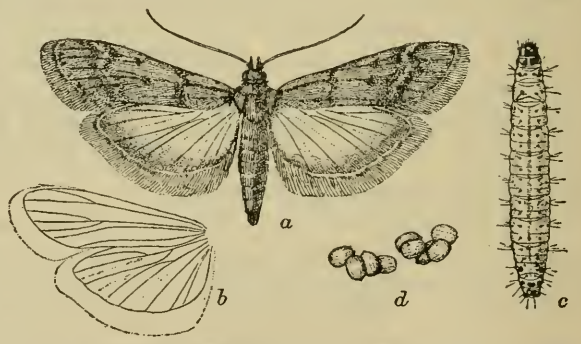


FIG. 2.—The fig moth (*Ephestia cautella*): *a*, Moth; *b*, denuded wing, showing venation; *c*, larva, dorsal view; *d*, two egg masses. *a*, *b*, *c*, Enlarged about four times; *d*, more enlarged. (From Chittenden.)

ECONOMIC IMPORTANCE OF DRIED-FRUIT INSECTS.

The annual financial loss to all who handle dried fruits from the Pacific coast would be very difficult to estimate, since these products are rapidly distributed by the packers over a large territory,

and the injury is first noticed by the retailer or the consumer. Moreover, the retailer is inclined to be somewhat reticent regarding the presence of wormy fruit in his establishment, although an examination frequently shows such to be the case. A few retail grocers stated that the "worms" were especially troublesome during the summer months, and while the majority of those interrogated admitted with reluctance that they ever received wormy fruit, it was, no doubt, present in their stores at the time. Many companies claimed that it would be difficult to secure the exact figures, but admitted that they usually sold a considerable quantity as hog feed during the season. A wholesale grocer stated that his annual loss on dried fruits returned because of insect infestation was about $50, but that the loss in 1912 approximated $150. These are only a few individual instances, and the greatest aggregate loss is through small quantities of infested fruit which are thrown away or sold as hog feed, the retailer preferring the loss of a small quantity of fruit to the trouble of returning it to the wholesaler. It is readily apparent, however, that the annual loss must in the aggregate be considerable.

For the reason that no estimates can be made of the injuries by the Indian-meal moth to fruits in California, it is worth stating that according to figures furnished by Dr. Chittenden in 1910, there was a loss to the peanut industry, through the ravages of this species, amounting to 20 per cent, or, at a conservative estimate, $3,000,000.[1]

PRELIMINARY OBSERVATIONS.

Observations begun in 1911 in central California, with headquarters at Sacramento, with special reference to insects attacking dried figs, were soon extended to all dried-fruit insects. It was found that in most cases insects were present in the field where the fruit is dried, that they were quite numerous around the packing houses, and that they were present in warehouses and stores in sufficient numbers to threaten severe infestation to boxes of dried fruit that might be stored there. There are usually one or more cracks or openings in the boxes (Pl. II, fig. 2) through which an insect or mite can readily crawl. The paper used in lining the boxes does not to any extent prevent their entrance.

These preliminary observations led to the conclusion that the problem could not be successfully combated by attacking it at any one point, but that the methods of drying, storing, processing, packing, and shipping should be investigated.

THE INDIAN-MEAL MOTH.

The life history of the Indian-meal moth (*Plodia interpunctella* Hübn.) will vary with the prevailing temperature, but was deter-

[1] Popenoe, C. H. The Indian-meal Moth and "Weevil-cut" Peanuts. U. S. Dept. Agr., Bur. Ent., Cir. 142, 6 p., 1 fig., Sept. 16, 1912. See p. 1.

mined at the Sacramento laboratory during June, July, and August, 1913, as follows: Egg stage, 6 days; larval stage, 35 days; pupal stage, 12 days; adult, about 14 days. Total, from egg to adult, 53 days, or 1 month and 23 days.

While the subject of this article is practical and based on conditions at Sacramento, Cal., it should be added that in the case of the life history of this species Dr. Chittenden has pointed out [1] that "experiment shows that the insect is capable of passing through all its several stages from egg to adult in five weeks, which furnishes a possibility of six or more generations in a well-heated atmosphere, although in a moderately cool granary or other storehouse four or five broods is probably the normal number per annum."

The sudden appearance of large numbers of larvæ in dried fruit is readily explained by Table I, which shows the number of eggs deposited by six moths which were confined in the laboratory to determine the rate of oviposition.

TABLE I.—*Egg-laying records of the Indian-meal moth.*

No.	Days.								Total.
	1st.	2d.	3d.	4th.	5th.	6th.	7th.	8th.	
1	46	79	36	23	24	16	11	.....	235
2	56	65	27	36	36	21	9	.....	250
3	39	43	34	18	16	6	.....	.....	156
4	16	33	47	64	45	56	12	13	286
5	59	51	55	38	26	5	.....	.....	234
6 [1]	.....	.....	.....	.....	.....	.....	.....	.....	168

[1] The number of eggs in this vial was determined as total and not by days.
Average number of eggs deposited by the six moths, 221.3.

These eggs were deposited mostly during the night.

The life cycle during the summer, as given in a preceding paragraph, is only 53 days. Starting with one fertile female in a packing house on June 15 (provided all of the insects matured), there would be 221 moths by the following August 15, and by August 30 (provided that half of these moths were females) there would be a total of 23,310 larvæ in the dried fruit.

Under natural conditions some of the eggs do not hatch and many of the larvæ fail to mature, but from the foregoing data it is readily understood that a few moths of this species are capable of producing a very severe infestation within a relatively short time, provided that temperature and other conditions are favorable.[2]

[1] Chittenden, F. H. Some Insects Injurious to Stored Grain. U. S. Dept. Agr., Farmers' Bul. 45, 24 p., 18 fig., 1897. See p. 10.

[2] The hymenopterous parasite *Habrobracon hebetor* Say is frequently found attacking the larvæ of the Indian-meal moth, but it has not been observed appreciably to affect the infestation in California.

FIG. 1.—THE INDIAN-MEAL MOTH (PLODIA INTERPUNCTELLA): MOTH ON A DRIED APRICOT. (ORIGINAL.)

FIG. 2.—THE INDIAN-MEAL MOTH: LARVA ON A DRIED APRICOT. (ORIGINAL.)

FIG. 1.—FIGS HANGING ON TREES DURING THE WINTER CONTAINING HIBERNATING ADULTS OF THE DRIED-FRUIT BEETLE (CARPOPHILUS HEMIPTERUS). (ORIGINAL.)

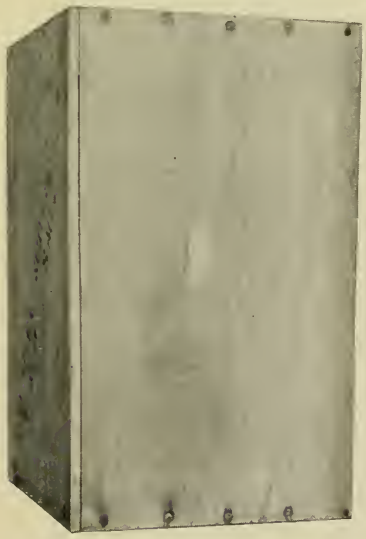


FIG. 2.—THE AVERAGE PACKING BOX, SHOWING CRACKS THROUGH WHICH DRIED FRUIT MAY BECOME INFESTED. (ORIGINAL.)

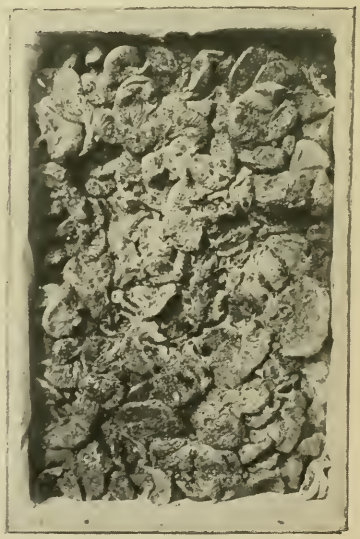


FIG. 3.—AN INFESTED BOX OF FIGS IN THE ORDINARY PACKING CASE. (ORIGINAL.)

HIBERNATION.

Partly grown larvæ brought into the laboratory October 10, 1913, spent the winter in that stage, pupated in the early spring, and emerged as adults April 16, 1914. Larvæ were observed at various times during the winter in dried fruit and partly spun up in corners and cracks of warehouses. Adults were not observed in warehouses until April 15, when many were found to be emerging. In California this insect appears to hibernate in the larval stage, pupate in the early spring, and emerge as an adult about the middle of April.

THE DRIED-FRUIT BEETLE.

The dried-fruit beetle (*Carpophilus hemipterus* L.) is probably the next in importance as a destructive dried-fruit insect. It is found in large numbers in the figs before they drop from the trees and in bins of figs and other dried fruits. The adults often frequent the packing houses in large numbers, where they swarm over and deposit eggs on the fruit which has been dipped and put out to cool. They breed readily in the moisture of the dried fruits, but apparently can not live in fruit that is moderately dry.

The adult insect hibernates in stored fruit in the packing houses, in figs, and probably in other fruits which are not gathered from the field at the time of harvest. Plate II, figure 1, shows figs which were allowed to remain on the trees during the winter, and which were later found to be highly infested with *Carpophilus hemipterus*.

On September 3, 1911, 5 pounds of dried figs, taken at random from each of seven different dryers in the vicinity of Fresno, Cal., were placed in boxes made insect-proof by plugging all cracks with cotton and wrapping carefully in stout paper. When examined January 13, 1912, the fruit in three of the seven boxes was badly infested. The results of this experiment prove that many figs are infested before they are shipped to the packing house and that the drying sheds are one of the sources of infestation. These conclusions will apply equally well to other fruits. The processing may kill the insects in the fruit at the time of processing but will not protect them from infestation while they are being dried or held in the drying sheds prior to shipping to the packing houses.

It has been found that infestation takes place in the field, in the packing house, in the warehouse, and in the grocery store.

PROCESSING DRIED FRUIT.

Dried fruit from the bins of the packing house is usually quite dry and not particularly attractive or appetizing in appearance. In order to improve its texture so that it will pack well and be attractive to the consumer, it is processed. In Table II will be found the formulas for processing fruit that are in common use in California.

TABLE II.—*Formulas for processing fruit in common use in California.*

Fruit.	Treatment in field.	In packing houses.	Processing.	Packed.
Peach....	Cut in half, sulphured 1½ hours, dried in sun on trays.	Graded and placed in bins not over 4 or 5 feet deep; sweating takes place.	Dipped in cold or lukewarm water, drained, and sulphured.	Moist.
Apricot..	Same as peach.....	Same as peach.....	Same as peach.....	Do.
Pear.....	.....do.....	Same as peach, but handled more carefully.	.....do.....	Do.
Prune....	Picked from ground, dipped in lye solution, rinsed in clear water, dried on trays in sun.	Graded and placed in bins.	Dipped 1 to 3 minutes in clear water at 212° F., drained.	Moist; warm.
Fig.....	Picked from ground and dried on trays; or dipped in hot brine, drained, dipped in cold brine-soda solution, drained, and spread on trays, placed in sun until excess moisture is removed, then stacked to complete drying.	.....do.....	Black figs, dipped in boiling brine, drained and packed. White figs, dipped in cold water, drained, and packed; or dipped in boiling brine, drained, and packed. Some are dipped and sulphured.	Do.

FORMULAS.

Brine formula for prunes: Lye, 1 pound to 20 gallons.

Formula for dip for figs before being packed: Salt, 50 pounds; soda, 3 to 4 pounds; water, 150 gallons.

Formula for raisins before drying: One quart olive oil and three-fourths pound powdered caustic soda; water, 1 gallon; cook 30 minutes, add 100 gallons of boiling water with 4½ pounds caustic soda; add more caustic soda if desired.

Amount of sulphur to use and time of exposure based on 1,000 pounds of fruit.

THE EFFECT UPON INSECTS OF PROCESSING FRUIT.

It will be observed in Table II that the processing includes either dipping in boiling brine or sulphuring.

In the case of figs, when removed from the dipping vat they were too hot to be handled. When opened the interior was steaming hot, and it was assumed that no insects could pass through the dip alive. To prove this point, the following experiments were conducted:

On September 3, 1911, 100 pounds of dried figs, thoroughly infested by the dried-fruit beetle and Indian-meal moth, were dipped in the regular dipping solution heated to boiling. Fifty pounds of these figs were immersed in the dip 45 seconds, and 50 pounds were immersed 90 seconds. The figs were protected from insects when cooling, and were later put into boxes and sealed. That this dipping was sufficient to kill all animal life was proved by the total absence

of living insects or of any trace of them when the fruit was examined four months later, January 14, 1912.

That sulphur fumes are more or less effective in killing insects has long been known, but in order to prove their efficiency the following experiments were conducted:

On September 4, 1911, 100 pounds of black figs, which were badly infested by the dried-fruit beetle, were separated and sulphured in the regular manner. Upon being removed from the sulphur box they were immediately placed in cartons and sealed to prevent reinfestation. They were examined January 14, 1912, and no insects or evidence of recent work were observed. The sulphuring killed all insects present in the figs at the time.

An experiment to determine the effect of sulphur fumes upon the eggs of insects was conducted at Sacramento during the summer of 1913. About 25 eggs of the Indian-meal moth, deposited on a dry fig in a vial, were placed in the top of a sulphur box and given the usual treatment. None of these eggs hatched, while the eggs kept as checks hatched in due time.

From the foregoing experiments it is evident that sulphuring the fruit has a tendency to kill any insects infesting it. In case eggs or larvæ are well inside of the fruit, however, it is probable that they would not be injured; and since the use of sulphur is not sanctioned by the authorities, and the use of heat, either wet or dry, is so very effective, the use of a belt heater is recommended.

A BELT HEATER TO DESTROY INSECTS IN DRIED FRUIT.

The belt heater is composed of a chamber in which is run a tier of belts, each running in the opposite direction to the one above it. These are so arranged that the fruit can be fed in at the top and will travel on the top belt until it reaches the roller, when it will fall to the belt below and be carried in the other direction, and so on down, the last belt carrying the fruit out of the chamber. A heater, either electric or steam, is arranged to maintain a temperature of 180° F., and by adjusting the speed of the belts the time that the fruit remains in the heater can be regulated.

An experimental machine consists of six belts, 10 feet long and 5 feet wide, running on 3-inch wooden rollers. The rollers are set on cold-rolled axles, turned by cast-iron sprockets connected by No. 25 chain, which is so arranged that it reverses the direction of alternate rollers. To insure even heating an electric fan is so adjusted that the hot air is blown along the belts, and guides are arranged to direct the air current onto the belts above. Thus, as the fruit is carried along by the belts, the hot air is blown over it. Such a machine arranged to deliver the fruit into a screened packing room (fig. 3) would insure the fruit against contamination before packing.

The fruit should remain in the heater sufficiently long to raise it to 180° F. This temperature will kill all insect life.

PROTECTING DRIED FRUITS FROM INFESTATION.

Although some damage results from the infestation of dried fruit stored in bins in the packing house, the greatest loss occurs after the fruit has been packed.

The fruit which is separated and dipped into hot solutions (212° F.) before being packed is by this process sterilized so far as insects are concerned. It has been found that such fruits as peaches, pears,

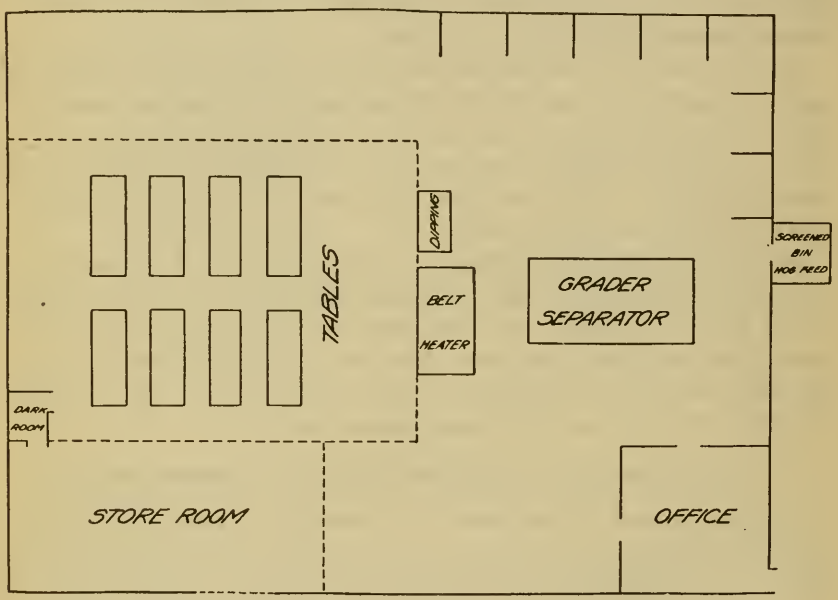


FIG. 3.—Diagram of screened packing room showing belt heater at center. (Original.)

and apricots, which are not dipped in such solutions, can be sterilized by dry heat before they are moistened, preparatory to packing. The major problem is one of preventing infestation after the fruit is sterilized and packed. Successful experiments with the use of a sealed carton (fig. 4) to protect cereals from insect attack[1] led the writer to work out a similar process for dried fruits.

Figs put up in small packages were found convenient for the following preliminary experiments begun at Fresno, Cal., October 1, 1913. Hot figs were taken from the dipping vat, pressed into bricks, wrapped in the regular paper, and placed in cartons. Careful watch was kept for infesting insects, and none was seen near the figs during the packing process.

[1] Parker, William B. A Sealed Paper Carton to Protect Cereals from Insect Attack. U. S. Dept. Agr., Bul. 15, 8 p., 8 fig., Oct. 16, 1913.

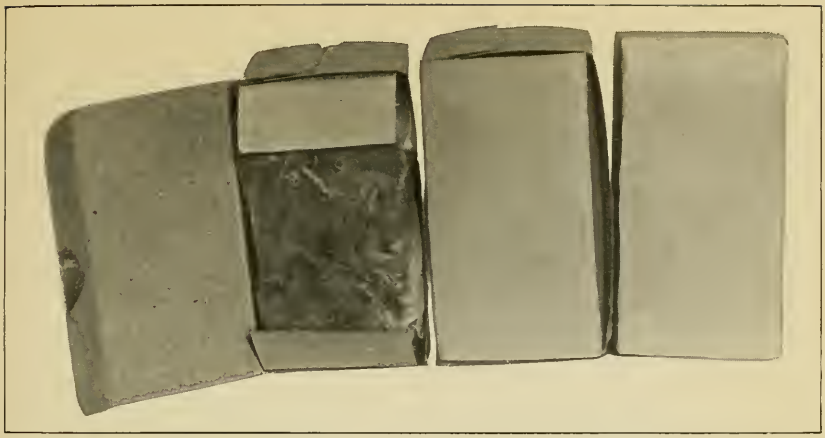


FIG. 1.—PATTERN OF THE INNER SEAL. (ORIGINAL.)

FIG. 2.—METHOD OF USING THE INNER SEAL. (ORIGINAL.)

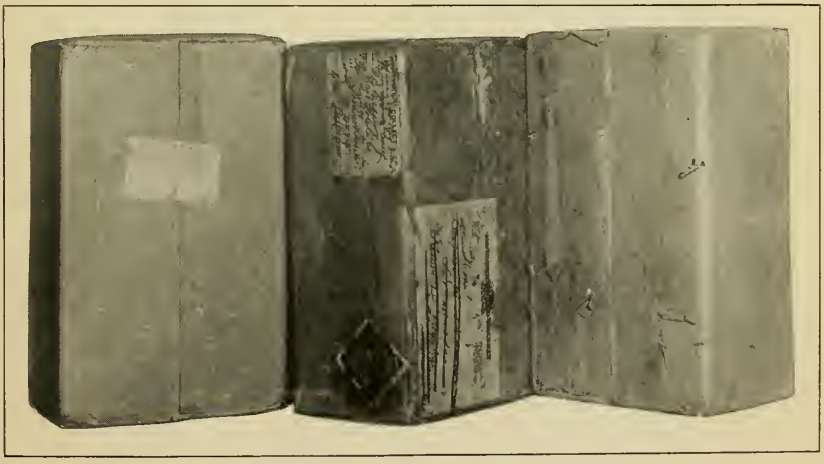


FIG. 3.—HOW THE PACKAGES STOOD THE SHIPPING TEST. (ORIGINAL.)

THE INNER SEAL: A SANITARY INSECT-PROOF PACKAGE.

FIG. 1.—ROUND PACKAGES FOR DRIED FRUIT WHICH CAN BE SEALED. (ORIGINAL.)

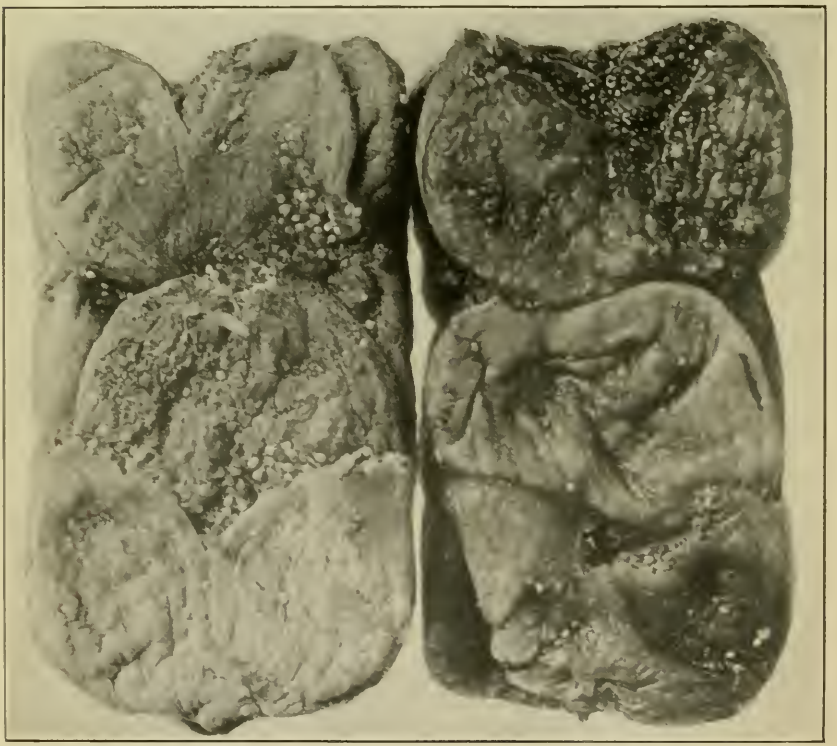


FIG. 2.—BRICKS OF FIGS, SHOWING THE RESULT OF SEALED CARTON EXPERIMENTS.

At left, unsealed brick. Note dried sugaring and infested condition. At right, sealed brick. Note moist condition. (Original.)

Of these cartons 16 were sealed as shown in Plate III, figure 1, and 16 left unsealed. Of the unsealed ones, 8 were so prepared that the wrapping paper was slightly torn. This condition is one frequently found in packages of figs put up by the girls in the packing house.

The 32 cartons prepared as described above were brought to Sacramento and placed in an insect-tight box in which were then placed large numbers of larvæ and adults of *Plodia interpunctella*, *Carpophilus hemipterus*, and *Gnathocerus* (*Echocerus*) *maxillosus* Fab. The box was then sealed so that the insects could not escape, and they were given every chance to infest the cartons.

At the conclusion of these experiments, April 16, 1914, all but two of the unsealed cartons were found to be infested, while the sealed ones showed no evidence of insects having entered. It was observed that the larvæ of *Plodia interpunctella* had in some places broken through the thin paper used to wrap the bricks of figs before they are placed in the cartons.[1] It had previously been supposed by the packers that this paper if preserved intact would prevent insects from reaching the fruit.

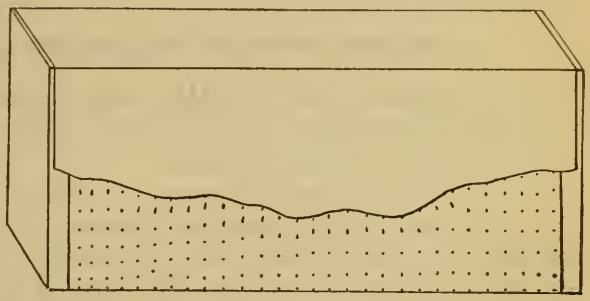


FIG. 4.—Diagram of carton, showing method of applying label to protect inclosed cereal from insect attack. (Author's illustration.)

The foregoing experiments will serve to prove the efficiency of a sealed carton in protecting packed dried fruit from insect attack.

SEALED PACKAGES FOR DRIED FRUIT.

Packages of dried fruit weighing less than 5 pounds are so nearly the size of the cartons used for cereals that, except for the high labor cost of sealing, the method used with the cereal carton could be readily applied to dried fruits. With the 10, 25, and 50 pound packages, however, the cost of such sealing is excessive, and the wooden boxes used can not be thus sealed to advantage, as the seal is easily broken by rough handling. To obviate this difficulty a light paper carton fitting inside the wooden box, and sealed before the top was nailed on, was constructed, but the cost of these cartons and the additional labor required to pack them prohibited the employment

[1] A heavy paraffined paper appears effective in preventing insects from eating through.

of this method. A fiber-board carton was then selected which could be sealed, or in which had been placed an inner seal, to prevent the entrance of insects. Such a package to be successful should stand the same shipping conditions as a wooden box and should not, when sealed, greatly exceed the latter in cost. A carton of the following specifications was tested to determine its shipping qualities:

Certificate of box maker.—This box is made of three-ply or more, fiber board or pulp board, outer ply waterproofed.

Each ply	inch..	0.016
Thickness not less than combined board	do....	.080
Resistance (Mullen test), combined board	pounds per square inch..	200
Dimension limit, length, width, and depth added	inches..	65
Gross weight limit	pounds..	65

SHIPPING TESTS OF FIBER-BOARD PACKAGES.

Three 25-pound boxes (Pl. III) made according to the foregoing specifications were filled with 25 pounds of dried peaches, sealed, and given the following shipping tests:

Box No. 1 was shipped by express from Sacramento, Cal., to Portland, Me., and back, or about 6,000 miles, during which trip it was handled by at least 18 men. This box arrived in Sacramento in good condition and is shown in Plate III, figure 3.

Box No. 2 was shipped from Sacramento, Cal., to Fargo, N. Dak., as one of the bottom boxes in a car of 25-pound boxes of dried fruit. Except for one place where the sharp edge of a wooden box had worked up the edge, this box arrived at its destination in fine condition, as illustrated in Plate III, figure 3. This rubbing would not occur in a carload of fiber-board boxes.

Box No. 3 was sent to San Francisco by Parcels Post, where it was trucked around the wharves, given a thorough test, and examined by several packers and by the agent of one steamship company. It arrived in Sacramento in good condition, after having stood the test and having been pronounced a good shipping package for dried fruit. (Pl. III, fig. 3.)

The foregoing tests proved that the 25-pound package of dried fruit could be shipped long distances, and its shipping qualities compared very well with the wooden box.

These fiber-board boxes (Pl. III) weigh much less than the wooden box, and the saving on the freight would be considerable. In the case of the 25-pound box the saving per car on the basis of $1.10 per 100 (freight rate) is about $23. It was estimated that the adoption of this style of package would save one company approximately $40,000 annually.

THE SEAL.

The fiber-board package was found to be tight, except at the corners and where the flaps meet in the middle of the sides. An attempt was made to seal these places with gummed tape, but the labor required to do this increased the cost of packing to such an extent as to make the method unfeasible.

An inner seal was then so constructed that when the carton was regularly sealed there would be no cracks or openings at the corners. (See Pl. III, fig. 1.)

The inner seal appears practical from the packer's point of view, but the carton manufacturer claims that it would be difficult to make it cheaply enough without special machinery, although this would probably be made were there a demand for such cartons.

ADVANTAGES OF THE SEALED CARTON FOR DRIED FRUIT.

As long as dried fruit can be processed so that mold is no more prevalent in sealed packages than in unsealed ones the disadvantages of this type of package, with the possible exception of the extra cost, are negligible. The advantages, on the other hand, are several.

The main object of the sealed carton is the exclusion of infesting insects. This is accomplished very successfully and so solves a large portion of the present problem.

It also prevents the evaporation of moisture from the fruit, and thus for a long time preserves the fruit in the same moist condition in which it was packed. Plate IV, figure 2, shows two bricks of figs packed October 1, 1913, and opened April 16, 1914. The brick on the left was put up in an ordinary carton, and, as will be observed, it was dried, sugared, and became infested, while the one on the right, which was put into an ordinary carton, but sealed, is in practically the same condition as when packed. These two bricks were kept under the same conditions; in fact, were in the same box. From the foregoing data it is evident that fruit properly packed in sealed cartons will be protected from infestation and will remain in a moist condition much longer than when packed in an ordinary carton or box.

OTHER SEALED PACKAGES.

In an attempt to find a small and attractive package for their fruit one packing company in California evolved a round carton with a cover that fitted over the end like the cover of a baking powder can, as shown in Plate IV, figure 1. A printed label pasted around the edge of the carton formed in experiment a very effective seal. This carton appears to be satisfactory for small packages, but the shape is such that more room is required for shipment than is the case with the square package, and it is not as practical for the larger sizes.

When objections to the inner seal were presented the writer immediately investigated other possible methods. Among several which were suggested, the use of a waxed sealing paper wrapped around bricks of fruit and sealed with a hot iron seemed very promising.[1] It was found that bricks of apricots, prunes, and pears up to 10 pounds in weight could be successfully made and wrapped in the waxed paper, and that by placing a piece of sheet iron on top of the brick of fruit before folding the paper over, a smooth surface could be obtained for the application of the sealing iron. After the top is sealed the sheet iron should be quickly removed. The hot iron may then be applied to the ends of the paper, making them tight, and afterwards the ends may be folded up and the brick placed in a large carton. Plate V, figures 1 and 2, shows the effect obtained by using such a paper seal, which, when properly sealed, renders the package insect proof. The cost of packing dried fruit in such a package has not been determined, but the writer believes that it will be found economical in many packing houses.

This method combines the advantages of an insect-proof package, a 5 or 10 pound unit, and a 25 or 50 pound fiber-board carton, which is lighter and probably cheaper than the wooden box.

While in the field the writer observed a package formed of an ordinary raisin carton which was sealed in a waxed sealing paper. The sealing was done by machinery which, except for the initial expense of the machine, would make the process very rapid and economical. Such a package might prove very efficient for dried fruits put up in from 1 to 5 or even 10 pound packages.

Several packers have reported the presence of mold in the ordinary wooden boxes of dried figs. Plate VI, figure 1, shows such a condition. This was observed to occur more frequently in the sealed round boxes previously mentioned, and it appears that if the sealed carton is to be used for dried fruit the problem is a very important one.

From examinations of moldy fruit and from investigations of the condition of the fruit when packed, the writer concludes that conditions favorable to the growth of mold occur only when the fruit is too wet when packed, either through excessive processing or improper drainage. One packer stated that when the fruit was taken directly from the hot dip and packed in sealed boxes a large percentage of the cartons became moldy. On the other hand, if the fruit was allowed to drain thoroughly and stand in lug boxes or in a heap for several hours before being packed, the moisture became equalized and mold rarely developed. (Pl. VI, fig. 2.) To establish these statements and observations finally the following experiments were conducted:

On July 28, 1914, four lots of figs were processed by dipping in boiling water for one minute. Lot No. 1 was dried in the sun until

[1] Suggested by Mr. J. H. Green, of San Francisco.

FIG. 1.—A CARTON WRAPPED AND SEALED BY THE MACHINE. (ORIGINAL.)

FIG. 2.—CLEAN AND WHOLESOME; MOISTURE AND INSECT PROOF. PARAFFIN-WAXED PAPER SEAL APPLIED TO A CARTON OF RAISINS. (ORIGINAL.)

INSECT-PROOF PRODUCTS OF THE WRAPPING AND SEALING MACHINE.

FIG. 1.—MOLDY CONDITION OF FIGS IN ROUND SEALED CARTON. FIGS PACKED TOO WET. (ORIGINAL.)

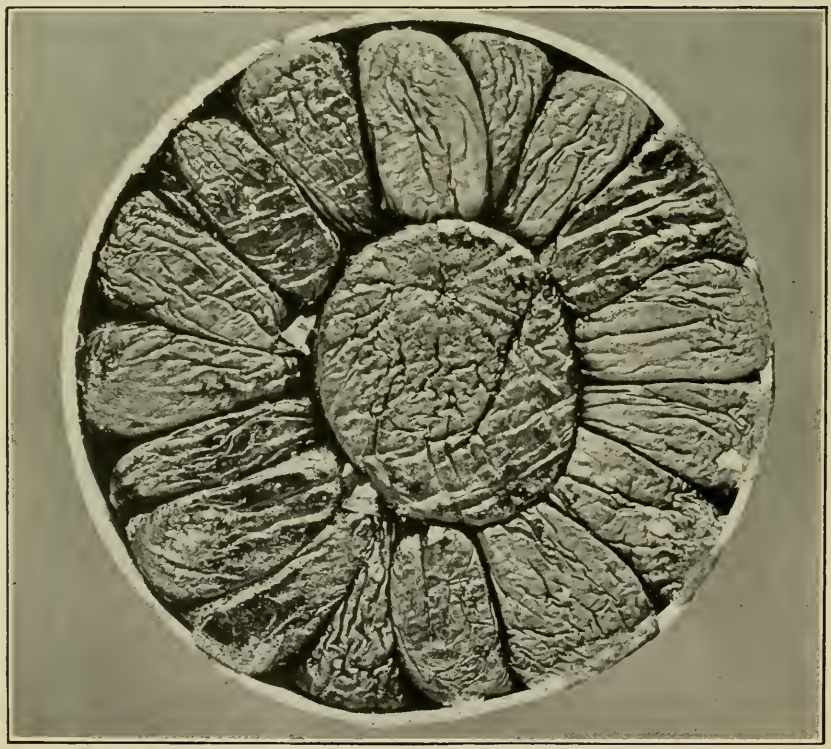
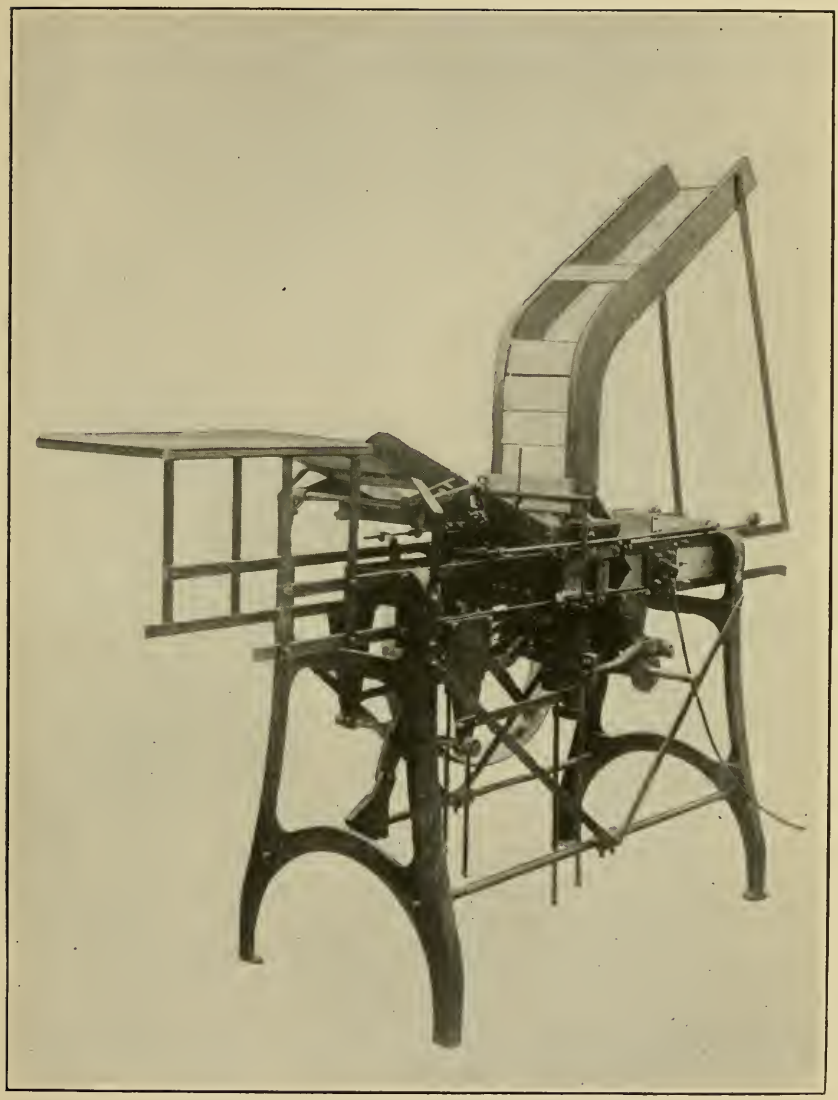


FIG. 2.—PERFECT CONDITION OF FIGS PACKED IN ROUND SEALED CARTONS. EXCESS MOISTURE REMOVED BEFORE PACKING. (ORIGINAL.)

PRESENCE OR ABSENCE OF MOLD IN SEALED CARTONS OF DRIED FIGS.



A VALUABLE ADJUNCT TO INSECT-PROOF PACKING.

A carton wrapping and sealing machine, with a capacity of 10,000 per day of 8 hours, at a total cost of less than $1 per thousand. (Original.)

all the surface moisture was gone. Lot No. 2 was dried in the sun a few minutes. Lot No. 3 was allowed to drain and cool thoroughly in the shade. Lot No. 4 was allowed to drain a few minutes and was packed while still hot and damp. All were packed in Mason jars, infected with spores from growing fungus, and sealed up.

On examination one month later no fungous growth was found to have developed on Nos. 1, 2, and 3, but No. 4, the lot which was packed wet and hot, had a very good growth of the fungus.

The experiment was repeated on September 1, dipping the figs in the hot water three minutes instead of one. On examination two weeks later it was found that in lot No. 1 no growth of fungus had developed. In lots 2 and 3 slight growths were present, and in lot 4 a heavy growth. The same figs were used in both experiments, and by the time they had been put through the boiling water the second time their surfaces were softer and stickier than they should be, and hence were good media for fungous growth.

These experiments confirm the earlier observations, namely, that figs thoroughly drained or dried and cooled before packing are less likely to develop fungous growth than those packed while still damp and warm.

A CARTON WRAPPING AND SEALING MACHINE.

Several machines are now being manufactured which do away with the slow and expensive method of wrapping and sealing cartons by hand. Such a machine is shown in Plate VII. The cartons are fed into the hopper at the top and the waxed paper is fed automatically or by hand. The machine wraps the waxed paper neatly and tightly around the carton and seals it air-tight by means of electrically heated plates. One operator is required when equipped with the automatic paper feed, and two without. This particular machine was made to wrap cartons 8 by 3 by 3 inches. It will wrap and seal a minimum of 25 to 30 per minute, or about 10,000 per day of eight hours. The cost based on this output, including the waxed paper, wrapping, sealing, power to operate, and wages of the operator, will be less than $1 per 1,000. The maximum output will be from 15,000 to 20,000 cartons per day, with a cost at this rate of from $0.80 to $0.90 per 1,000.

At present, by the hand-wrapping method, one girl will average 1,000 cartons per day. Thus the machine will easily do the work of a dozen or more girls.

The cost of hand-wrapping the package referred to is given as $1.75 per 1,000. Using the minimum output of the machine for comparison, the saving in one day's run would be over $7, at which rate the machine would pay for itself in less than four months, since it may be purchased capable of handling any size of carton desired by the purchaser at a retail price of about $600.

A machine of this nature would be available and practical not only for wrapping and sealing cracker and cereal cartons, but also for raisins, currants, figs, prunes, and all small packages of other dried fruits.

PREPARATION OF A STERILE PACKAGE OF DRIED FRUIT.

A description has been furnished of a method of preparing packages of cereals so that they will not become infested. This process is being successfully carried out by several large mills, the only real difficulty arising from the cost of sealing the carton. This objection is being gradually overcome.

The process consists in running the cereal through a sterilizer and then through a clean chute directly into an insect-free packing room, where it is packed in sterilized cartons and sealed. The writer believes that such a process can be applied to dried fruit, and the following suggestions are made to that effect:

In order to sterilize the fruit so far as insects are concerned it is necessary to heat it to 180° F. With the fruits which are regularly dipped in hot solutions this heating is readily accomplished, but in the case of those which are dipped in cold solutions before being packed the use of the belt heater described on pages 7–8 is suggested.

After sterilization by one of the foregoing processes the fruit must be protected from reinfestation, and the use of the screened packing room, a plan for which is shown on page 8, figure 3, and described below, will serve this purpose nicely.

The fruit should be run directly from the sterilizer or dipping vat into the packing room, where it is packed and sealed. It may then be removed to a warehouse, and if properly sealed it will not become infested by insects.

THE SCREENED PACKING ROOM.

A simple packing room (fig. 3) can be cheaply constructed by covering a light framework with lath, cloth, and paper. The windows, the floor, and all corners and joints should be made tight, and ventilation accomplished by blowing air through an opening covered with cheesecloth or No. 20 screen wire. Such a packing room can be constructed to admit plenty of light and air and still be free from insects. Whenever necessary the openings may be closed and the room thoroughly fumigated.

NOTE.—The writer has observed as many as 10 eggs of insects on the inside of a carton in a cereal mill. It is advisable, therefore, to sterilize all cartons before filling them. This may be readily done by placing a truck load in a heating chamber over night or during the day.

SUMMARY AND CONCLUSIONS.

The foregoing observations and experiments have brought out the following points:

A considerable financial loss due to the infestation of dried fruit by insects is experienced by packers, wholesale men, and retail dealers.

There are several species of insects which attack dried fruits on the Pacific coast, but of these the most common and destructive are the Indian-meal moth and the dried-fruit beetle.

Infestation takes place in the packing house, in the warehouse, and in the grocery store. The insects find their way to the fruit through small cracks in the boxes and between the folds of the paper.

All insect life is destroyed in fruits that are put through the boiling dip, and the processing of other fruits can be accomplished by the addition of the belt heater to sterilize all fruit so treated.

The use of an insect-free packing room and sterilized cartons or containers which are sealed before being placed in the warehouses or cars will protect the fruit from infestation unless the package is broken.

There are several cartons and methods of sealing that can be applied to dried fruit, but their cost will determine their practicability.

The secret of preparing an insect-free package of dried fruit is to sterilize it at a temperature of 180° F. and protect it from future infestation by the use of the insect-free packing room and sealing in sterile cartons or packages.

The sealed carton not only protects the fruit from infestation, but it prevents it from drying out and preserves it for long periods in the moist and attractive condition in which it was packed.

Moist fruit can be successfully packed in sealed cartons, provided attention is paid to the moisture content. The fruit must be carefully drained and must not be packed too hot.

Machines have been invented which will successfully wrap and seal small packages of dried fruit at a moderate cost per thousand.

It is probable that the time is coming when it will be as necessary to put up dried fruit in sealed packages as it is to pack cereals in that form to-day.

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IV. INSECTS.

BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 239

Contribution from the Bureau of Entomology, L. O. Howard, Chief.

June 24, 1915.

(PROFESSIONAL PAPER.)

THE EGGPLANT LACE-BUG.[1]

By

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(In cooperation with the Virginia truck experiment station, Norfolk, Va.)

INTRODUCTION.

Injury to eggplant by lace-bugs (Pl. I) first attracted the attention of the writer during the spring and summer of 1913. In the vicinity of Norfolk, Va., eggplant was found to be infested by a species at that time undescribed. It proved to be *Gargaphia solani* n. sp., the designation being given by Mr. Otto Heidemann, of the Bureau of Entomology. Owing to pressure of other work during the season of 1913 no further attempts were made at the time to study the insect to any great extent, but it was noted to feed extensively on eggplant, the leaves of which turn yellow and finally shrivel up. During the spring and summer of 1914 it again came under observation, investigation proving it to be widely distributed in Tidewater Virginia. In fact, wherever eggplant was grown on a commercial scale the lace-bugs were feeding. It was then considered advisable to make a careful study of the habits of this insect in view of its wide economic importance, and at the same time to devise and test methods for its control.

NATURE OF ATTACK.

In the early nymphal stages lace-bugs resemble the young of aphides; and since they procure their food by suction, the injury resulting to the plants (Pls. II, III) is indicated by a characteristic yellowing of the leaves. All stages may be found on the underside of the leaves, and in the nymphal stages, particularly, they always feed in original colonies as hatched. The first stage of injury appears in the form of circular discolored areas of about the size of a silver quarter. Such a leaf when examined will show a mass of eggs, and

[1] *Gargaphia solani* Heidemann.

Note.—This bulletin deals with a new enemy of eggplant and related plants. It will be of interest wherever these plants are grown commercially.

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usually the female also will be observed either in close proximity feeding or in the act of ovipositing. Upon the emergence of the nymphs from the eggs the discoloration of the leaves increases in area until finally the entire leaf is involved, turning yellow and dry.

The nymphs migrate from one leaf to another, injuring every leaf attacked, until they transform, after which, as adults, they disperse to other plants. Not every plant in a field will be injured, but once a plant becomes infested every leaf may be so injured as to result in the loss of the plant.

The truckers in the vicinity of Norfolk, Va., usually raise eggplant in fields of from 6 to 10 acres. During the summer of 1914 many such fields were carefully examined, and the injury was estimated at from 10 to 15 per cent of the entire acreage. The uninformed trucker does not as yet recognize this insect as a specialized eggplant pest, since the injury closely resembles that due to aphides. As the plant-lice are feeding on the eggplant at about the same time, the lace-bug injury is usually attributed to them. The injury to eggplant by this tingitid is entirely well defined and individual in character, and no one who has carefully observed the damage would ever confuse it with that due to the work of aphides.

DESCRIPTION OF STAGES.

THE ADULT.

This interesting lace-bug belongs to the heteropterous family Tingitidæ, which contains a number of injurious forms affecting certain of our native trees and shrubs. Although many species are found in some tropical countries, those occurring in the United States are comparatively few in number.

The eggplant lace-bug is one of the larger species of the United States and differs considerably in appearance from the others by reason of its prominent lacelike hood extending back of the head and the lacelike venation of the wings. The adult (Pl. I, fig. 2) is depressed or flat bodied, grayish to light brown, about 4 millimeters ($\frac{3}{16}$ of an inch) in size, and derives its popular name from the delicate lacelike structure of the wing covers.

Following is a technical description of the adult by Mr. Otto Heidemann:[1]

> Body rather flat; dark brown; angulated; yellow rim of the rostral groove very distinct at base of metasternum. Head dark, deeply punctured; at frontal part three small slender spines, the upper one more prominent; two others near to the eyes a little longer. Antennæ quite long, hairy; basal joint comparatively thick, black, and somewhat longer than the terminal joint, which is fusciform and black at the apex; second joint the shortest, testaceous; third more than four times as long as the fourth joint, yellowish white; bucculæ moderately expanded, yellowish, with one row of minute areoles.

[1] Heidemann, Otto. A new species of North American Tingitidæ. *In* Proc. Ent. Soc. Wash., v. 16, no. 3, p. 136–137, 1 fig., Sept. 26, 1914.

Pronotum feebly convex, black, with three low yellowish carinæ, the median one a little higher before the middle, tapering toward the pale apex of the triangular posterior portion of the pronotum; the lateral membranous part of the pronotum angularly expanded, with two to five series of irregular areoles, the edge somewhat broadly reflexed, some of the nervures exteriorly blackish. Head, pronotum, and the edge of the membranous dilation densely covered with fine, soft hairs; pronotal hood rather large, much longer than wide, covering the hind part of the head, leaving the eyes free; surface yellowish white, opaque, with fine minute areoles. Hemelytra extending about one-third beyond abdomen; oblong-oval, broadly rounded at the end, feebly sinuate toward the base; the discoidal areas pyriform, reaching to about the middle of the elytra, reticulated, blackish at base and at apex, a pale stripe across the middle, the subcostal biseriate, yellow; costal margin yellowish-white, translucent with four or five series of medium-sized areoles at the widest part, those toward the base smaller; five transverse oblique nervures black at the costal area and all nervures at the apex more or less blackish. Legs pale, yellow. Length, 4 mm.; width, 2 mm.

The following descriptions of the immature stages are by the writer:

THE EGG.

Length 0.37 mm., width 0.18 mm. Color light to dark greenish at base, gradually assuming brownish toward the apex. Top of egg crater-like, with whitish lacelike border, and screwlike rim. The entire egg resembles a miniature bottle. The eggs are attached to the underside of the leaves by their bases and usually lean in all directions and at almost every angle.

THE NYMPHAL STAGES.

First stage.—Length 0.3 to 0.4 mm, width 0.12 mm. The newly hatched nymph resembles a newly born aphis, is white to light yellow, with pink eyes, long legs, and antennæ as long as body.

Second stage.—Length 0.8 mm., width 0.19 mm. Color yellow. Antennæ as long as body; the last segment clublike, covered with setæ; last segment of the legs possessing a pair of claws. There are spines on each side of the thorax and from each segment of the abdomen.

Third stage.—Length of body same as in the previous instar; width decidedly more, 0.30 mm. Spines on lateral margin and on dorsal surface of body. First indications of wing pads occur in this stage by the swelling of lateral margins of the thorax.

Fourth stage.—Length 1.5 mm., width 0.8 mm. Body oblong-ovate, yellowish. Head dark yellow, hood prominent; wing pads extending to second abdominal segment. Entire body covered with spines, the position of which is discussed in the following nymphal stage. Antennæ as long as body, light brown.

Fifth stage.—Length 2.2 mm., width 1.2 mm. (Pl. I, fig. 2.) Body oblong-ovate, yellowish except at margin of abdomen, where it is light yellow with dark patch at the apex. On the lateral margins of each side of first three abdominal segments a tubercle rises directly from the surface, and from the last six abdominal segments rise prominent spiny processes. From the middle of each of first and second abdominal segments there rise two hornlike spiny processes, and one from the fourth, fifth, and seventh segments dorsally. One spiny process and some tubercles on the lateral margin of the wing pads; two large spiny processes placed near together on the metanotum, and tubercles at each side of thorax. On each lateral margin of the hood there is a spiny process and some tubercles; two prominent spines are located centrally, and a small pair nearer the head. The head carries three strong spines in front, one long and two shorter ones; two large, strongly curved, hornlike spines at the base near the eyes. All spiny processes except on the lateral margins of the sixth, seventh, and eighth abdominal segments dark brown; those on latter light yellowish. Head yellowish brown; eyes prominent; thorax dark yellow; wing pads light yellowish with dark margin at base, extending to fifth abdominal segment. Antennæ light brown, as long as body.

DISTRIBUTION.

The collection of Tingitidæ at the U. S. National Museum contains few specimens of this species. These have been recorded by Mr. Heidemann in his paper as follows: Kirkwood, Mo., August 10 (Riley, Pergande), found on *Solanum carolinense* and *Solanum elaeagnifolium;* Lavaca County, Tex., June 21; Columbus, Tex., July 29, 1879 (Riley collection), on coffee weed (*Cassia* sp.) and *Solanum* sp.; El Reno, Okla., July 12, 1909; Norfolk, Va., June 12, 1913 and 1914 (Fink), and the author stated at the time "It is recorded as found on eggplants in great abundance." The species was also found by Dr. F. H. Chittenden, August 12, 1913, and later, and by others, including the writer, in the District of Columbia, and by the writer in Maryland and at Occoquan, Va. Judging from the localities already known it is a native American species and seems to have a range of distribution extending from the South Atlantic coast to the Southwestern States.

SEASONAL HISTORY.

THE ADULTS.

Early in spring, almost as soon as eggplants are set in the field, the hibernating adults begin to infest them and establish colonies. Thus adults and eggs were found as early as May 20. The adults reproduce and feed the entire summer on the eggplant, but migrate to the horse nettle (*Solanum carolinense*) during the latter part of August and the first week in September, when the season for eggplant is about over. Here they continue breeding until cold weather sets in. The adults hibernate in the shriveled leaves or in the ground under débris, reinfesting the next crop when set out.

The egg-laying period in the field lasts from four to five days. In the laboratory the duration is slightly longer, the temperature averaging 75° F. Table I indicates the date and number of eggs deposited by three females confined in the laboratory.

TABLE I.—*Number of eggs deposited by females of the eggplant lace-bug, Norfolk, Va., 1914.*

Female A.		Female B.		Female C.	
Date.	Number of eggs.	Date.	Number of eggs.	Date.	Number of eggs.
June 16	57	June 24	30	July 12	28
June 18	30	June 25	41	July 13	31
June 20	34	June 27	23	July 15	42
June 22	44	June 29	23	July 19	15
June 24	23				
Total	188		117		116

Females that were observed in copulation on July 12, 1914, gave the first complement of eggs July 14, 1914.

FIG. 1.—LAST NYMPHAL STAGE OF THE EGGPLANT LACE-BUG. GREATLY ENLARGED. (ORIGINAL.)

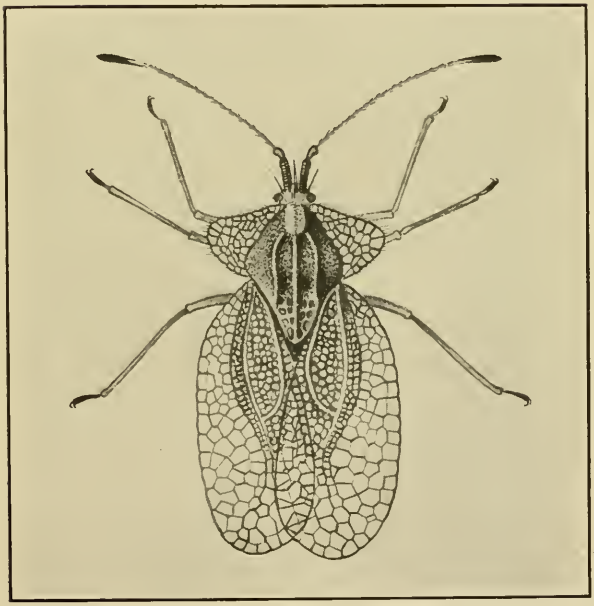

FIG. 2.—ADULT OF THE EGGPLANT LACE-BUG. GREATLY ENLARGED. (ORIGINAL.)

THE EGGPLANT LACE-BUG (GARGAPHIA SOLANI).

SURFACE OF EGGPLANT LEAF, YELLOW AND DRY AS A RESULT OF LACE-BUG ATTACK. (ORIGINAL.)

WORK OF THE EGGPLANT LACE-BUG.

UNDERSIDE OF EGGPLANT LEAF INJURED BY LACE-BUGS. (ORIGINAL.)

WORK OF THE EGGPLANT LACE-BUG.

UNDERSIDE OF LEAF OF EGGPLANT WITH ALL STAGES OF THE LACE-BUGS. (KILLED BY FISH-OIL SOAP, 7 POUNDS, TO 50 GALLONS OF WATER. NORFOLK, VA., 1914.) (ORIGINAL.)

WORK OF THE EGGPLANT LACE-BUG.

LAST NYMPHAL STAGE OF THE EGGPLANT LACE-BUG ON UNDERSIDE OF EGGPLANT LEAF. NORFOLK, VA., 1914. (ORIGINAL.)

THE EGGPLANT LACE-BUG.

Spraying Eggplants for the Eggplant Lace-Bug. Norfolk, Va. (Original.)

THE EGGPLANT LACE-BUG.

THE EGGS.

The minute greenish eggs are deposited on the underside of the leaves in circular masses of about 116 to 188. Their bases are attached in irregular rows, not erect, but, as before stated, leaning in different directions and at different angles. A sticky secretion is spread over the eggs after oviposition. To the unaided eye the eggs appear like a mass of mere dots on the underside of the leaf, occupying an area of leaf surface about one-half inch in diameter. The female attends the eggs during the entire period of incubation, leaving them only at intervals to feed, and later, when the nymphs emerge, is constantly in attendance.

Table II indicates the normal period of incubation for the summer months. Since not all the eggs are deposited at one time by the female, the emergence of the nymphs extends over several days. The table, however, refers to dates when nymphs first began emerging.

TABLE II.—*Incubation period of the eggplant lace-bug, Norfolk, Va., 1914.*

No.	Date of deposition of eggs.	Date of emergence of nymphs.	Incubation period.	No.	Date of deposition of eggs.	Date of emergence of nymphs.	Incubation period.
			Days.				*Days.*
1	May 24	May 30	6	6	June 23	June 28	5
2	May 25	May 31	6	7	June 23	June 29	6
3	June 15	June 23	8	8	June 26	July 3	7
4	June 17	June 24	7	9	July 4	July 19	5
5	June 21	June 26	5				

THE NYMPHS.

The nymphs are always found feeding in groups (Pls. IV and V). After the first molt they become yellow and at the same time shift their feeding position on the leaves. When migrating from one leaf to another the female adult usually directs the way, and with her long antennæ keeps the nymphs together or rebukes any straggler or deserter. It is an interesting sight to observe the migration of a colony of more than a hundred nymphs, with the female adult hurrying from one end of the flock to the other, keeping them together, and at the same time urging them in the right direction during the migration. When a new area has been selected the nymphs settle down, insert the proboscis, and begin to feed.

In its undeveloped forms, particularly in its last two nymphal stages, the eggplant lace-bug is an interesting and grotesque-looking object. The head and body are covered with spiny processes the function of which is not yet well understood. Some of the spines on the head are hornlike and, situated as they are near the eyes, they resemble very much the horns of some domesticated animals.

That the adult female keeps a watchful eye for intruders and enemies while in attendance on the nymphs is attested by the following

observation: On one occasion while observing the feeding of the nymphs a ladybeetle (*Hippodamia convergens* Guer.) was seen to approach the brood, when the adult lace-bug in attendance on the nymphs, with outstretched, slightly raised wings, suddenly darted toward the intruder, driving it from the leaf.

From the time the nymphs are born until they reach the adult form they pass through five distinct molting periods, and when temperature and other conditions are normal the time between molts is quite constant. From Table III it will be observed that two days is the usual period between molts.

TABLE III.—*Molting stages of nymphs of the eggplant lace-bug, Norfolk, Va., 1914.*

No.	Date hatched.	First molt.	Second molt.	Third molt.	Fourth molt.	Fifth molt.	Adult.
1	.....	July 9	July 11	July 13	July 15	July 17	
2	.....	...do.....	...do.....	...do.....	...do.....	...do.....	
3	.....	...do.....	...do.....	...do.....	...do.....	...do.....	
4	.....	July 10	July 12	July 15	July 17	July 18	
5	July 7	July 9	July 11	July 13	July 15	...do.....	Adult.
6	.....	...do.....	...do.....	...do.....	...do.....	July 17	
7	.....	...do.....	...do.....	...do.....	...do.....	...do.....	
8	.....	...do.....	...do.....	...do.....	Dead.	...do.....	
9	.....	...do.....	...do.....	...do.....	July 15	...do.....	

LIFE CYCLE AND NUMBER OF GENERATIONS.

Since two days represents the duration of time between molts, the life of the nymph from the egg to the last nymph, under normal conditions, is 10 days. Allowing six days for the egg stage and several days for time before and after copulation by adults, the life cycle is approximately 20 days.

In the vicinity of Norfolk, Va., this lace-bug was found breeding as late as November, giving a breeding season of nearly six months. There is a possibility of from seven to eight generations a season. Apparently six generations are spent on eggplant and the remainder on horse nettle.

Most of the generations in the field overlap, and the following observations made during the summer of 1914 indicate that six generations are spent on eggplant.

First generation, May 24.
Second generation, June 11.
Third generation, July 7.
Fourth generation, July 26.
Fifth generation, August 15.
Sixth generation, September 4.

In the region of Norfolk, Va., as stated before, the growing season for eggplant ends about the last of August or the first week in September, after which the lace-bug is found on the horse nettle (*Solanum carolinense*), where it continues to feed. It undoubtedly produces several generations on this plant, for as late as November all stages of the insect, including eggs, were found on it.

NATURAL ENEMIES.

Several predaceous insects were observed feeding on the nymphs and adults of the eggplant lace-bug. The species of ladybeetles common in this section, *Hippodamia convergens* Guer. and *Megilla maculata* De Geer, in both the larval and adult forms feed on the nymphs and adults of this lace-bug, usually turning them over on their backs before feeding. A common soldier-bug, *Podisus maculiventris* Say, feeds on the nymphs. Another common hemipteron found feeding on the nymphs is *Triphleps insidiosus* Say. Three species of spiders, *Epeira domiciliorum* Hentz, *Plectana stellata* Hentz, and *Chiracanthium inclusum* Hentz, identified by Mr. Nathan Banks, of the Bureau of Entomology, were observed feeding on all stages of the lace-bugs. It was not uncommon to find many lace-bugs with the head severed and the body mutilated. A very few specimens of a hymenopterous parasite were reared with the adult lace-bugs; this was identified as *Microdus* sp.[1] but it was not positively proved to attack the lace-bug.

METHODS OF CONTROL.

June 17 and 18, 1914, a series of spraying experiments against this lace-bug was undertaken in which the comparative values of fish-oil soap and various strengths of a standard blackleaf tobacco extract containing 40 per cent active nicotine sulphate were tested. (See Plate IV.) The results were quite satisfactory.

TABLE IV.—*Spraying experiments against the eggplant lace-bug, Norfolk, Va., 1914.*

No.	Fish-oil soap.	Nicotine sulphate.	Nymphs killed (per cent).	Adults killed (per cent).
1	1 pound to 50 gallons of water	1 to 1,066	80 to 85	None.
2	do	1 to 800	90	None.
3	do	1 to 640	85 to 90	None.
4	2½ pounds to 50 gallons of water		80 to 85	None.
5	3 pounds to 50 gallons of water		90	None.
6	5 pounds to 50 gallons of water		95	None.
7	6 pounds to 50 gallons of water		100	40 to 50
8	7 pounds to 50 gallons of water		100	90 to 95
9	8 pounds to 50 gallons of water		100	95

From the above table it will be readily seen that the percentage of nymphs killed was but slightly affected by the increase in the amount of the nicotine sulphate, and that the latter had no effect whatever on the adults; whereas with each increase in the amount of fish-oil soap there was a corresponding increase in the percentage of nymphs killed, until finally we arrive at a strength which will affect the adults. Above that strength we may then get perfect control of both the nymphs and adults.

Too much emphasis can not be laid on the thoroughness with which the spraying should be performed. It is particularly essential that the underside of the leaves be thoroughly covered by the spray.

[1] Chttn. No. 1373[01].

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 243

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER July 24, 1915.

CONE BEETLES: INJURY TO SUGAR PINE AND WESTERN YELLOW PINE.

By JOHN M. MILLER,
Entomological Assistant, Forest Insect Investigations.

INTRODUCTION.

A class of damage which has been termed "blighted cones" occurs frequently in the seed crops of sugar pine throughout its range in California and Oregon and of western yellow pine in the Pacific coast and southern Rocky Mountain regions. This damage is distinguished by the dying of the immature cones soon after the starting of the second year's growth. The dead blighted cones, which are less than one-half the size of normal cones, are withered and faded to a reddish brown. The blighted sugar-pine cones fall to the ground during the first summer, whereas the blighted yellow-pine cones may adhere to the branches for several years.

INSECTS CAUSING DAMAGE.

The greater part of this damage[1] is caused by small scolytid beetles, which have been identified by Dr. A. D. Hopkins, of the Bureau of Entomology, as *Conophthorus* spp. The common name of "cone beetles" seems most appropriate for these insects, as their life history and the damage caused by them relate entirely to the cones of the host trees.

The adults are small, black, cylindrical beetles, from 3 to 4 mm. in length. The adult beetle bores a small tunnel through the axis of the cone, wherein the eggs are deposited. The larvæ, tiny white grubs from 3.5 to 4.5 mm. in length when full grown, feed upon the scales, seeds, and tissues of the withering cone.

The pupæ, which differ but little in size and color from the larvæ but possess the form of the adult, are formed within the same cone

[1] The caterpillars of certain cone moths also kill immature second-year yellow-pine cones, in such a way that the damage resembles the work of the cone beetle, but this damage may be readily recognized by the character of the attack. In the areas observed by the writer the cone worms cause less than 10 per cent of the blighted cones.

NOTE.—This bulletin is the result of field observations made in Oregon and California. It is suitable for distribution on the Pacific coast.

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in which the larvæ develop. The brood of new adults is also formed in the same cone, and here the adults overwinter.

THE SUGAR-PINE CONE BEETLE.

(*Conophthorus lambertianae* Hopk.)

SEASONAL HISTORY.

Frequent observations in the field were made during the season of 1914 in the vicinity of Ashland and Colestin, Oreg., and near Hilt, Cal., at elevations ranging from 3,800 to 4,200 feet. The area near Hilt was located where the timber-felling operations of the California Fruit Growers' Supply Association were conducted, where seed-bearing sugar-pine trees were felled daily.

The brood of adults which overwinters in the cones infested during the previous spring and summer emerges the following spring. Records kept during the seasons of 1913 and 1914 from various lots of rearing material show that the maximum spring emergence occurs during May (see Table I, p. 3). Emergence from material collected in the fall and kept over winter in the laboratory has varied anywhere from April 19 to June 13. Emergence from material collected in the spring which had overwintered in the field and then was kept outside in muslin rearing sacks occurred from May 8 to 31. Frequent examination of cones in the field also showed that the emergence is occurring during this period and that it reaches its maximum between May 15 and June 1. The first attacks noted upon the 1913–14 cones occurred between May 25 and June 1. Continued fresh attacks were observed until about June 20. The following description covers all observations regarding the method of attack and subsequent habits of the beetle:

Sugar-pine cones at the beginning of the second-year growth are about 2 to 2½ inches long and are attached to the limb by a stalk from 2 to 3 inches long. The parent adult beetle attacks the cone by boring into the stalk of the cone. The position of this initial entrance varies greatly; usually it is just above the base of the cone, but it may occur anywhere from the base of the cone to an inch or more above. The wound made by the beetle soon produces a flow of resin which gradually accumulates on the surface in the form of a small pitch tube (Pl. II, fig. 1). After boring into the center of the stalk the beetle turns toward the cone and continues to extend its tunnel straight outward through the axis of the cone (Pl. II, fig. 2). After it advances well into the heart of the cone the tunnel becomes the egg gallery, and single eggs are deposited at intervals in notches excavated along the sides of the burrow. The entire length of the egg gallery is packed with sawdust. Sawdust is also packed around the eggs in the egg notches (Pl. II, fig. 2).

The rate at which the egg gallery is advanced by the adult has not been definitely determined, as it is impossible to determine the

progress made by the adults without cutting the cone open, and when thus disturbed the adult at once ceases its work. However, it has been observed that the egg gallery has been extended entirely through the small cones within five to eight days after attack. For the same reason the period of incubation of the eggs within the cone has not been definitely determined. In cones cut open, eggs that had apparently just been deposited incubated in from two to four days.

One pair of parent beetles are found in each of these egg galleries. A series of specimens collected from individual cones was submitted to Dr. A. D. Hopkins, and from his determination of sex it was found that one male and one female beetle occupy each egg gallery. As a rule but one pair of beetles attack a single cone, but in some instances three pairs of beetles have been found advancing as many egg galleries in the same cone. The sex of the parent which makes the initial attack on the cone and begins the excavation of the egg gallery has not been determined.

The immediate effect of this attack on the cone is to check all further growth. Eventually the infested cone withers, then becomes dry and hard, but for a period of time it hangs on the tree in a semi-moist and souring condition. It is during this period that the eggs of the beetle incubate and the young larvæ develop. The condition of the cone may be compared to that of the cambium of a pine which has been infested by Dendroctonus, and is in a fading or dying condition while the larvæ of the new broods of beetles are developing.

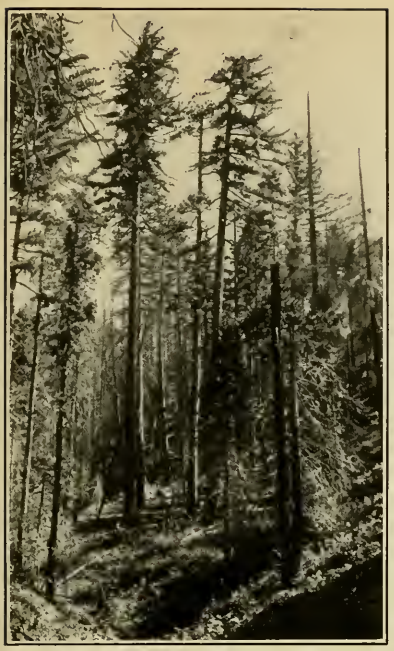
TABLE I.—*Emergence record of the sugar-pine cone beetle (Conophthorus lambertianae) in California and Oregon, 1913–14.*

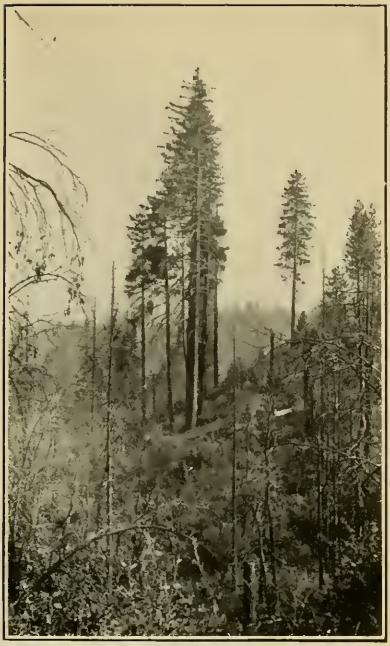
Hopk. U. S. No.	Locality.	Date of collection.	Material.	Period of spring emergence of overwintered adults.	Remarks.
11471a	Kyburz, Cal..	Apr. 11, 1913	Overwintered adults in 1911–12 cones.	May 19–May 31, 1913; 43 adults.	Breeding cage kept outdoors.
11498	Pino Grande, Cal.	May 11, 1913	.....do.....	May 14, 1913; 12 adults.	Do.
10802	.....do.....	May 26, 1913	.....do.....	Emerging May 26, 1913.	A considerable percentage of unemerged adults still in cones.
10833a-2	Hilt, Cal.....	July 11, 1913	New adults in 1912–13 cones.	June 4, 1914; 6 adults.	Breeding cage kept in laboratory. Heavy emergence during Aug., 1913.
10833a-3	Ashland, Oreg.	Sept. 5, 1913	.....do.....	Apr. 19–June 4, 1914; 16 adults.	Breeding cage kept in laboratory.
10838a-2	Little Butte Creek, Oreg.	Aug. 23, 1913	.....do.....	Apr. 25–May 21, 1914.	Do.
11371a	Hilt, Cal.....	Nov. 13, 1913	.....do.....	June 2–June 13, 1914.	Do.
10871a-2	.....do.....	May 2, 1914	Overwintered adults in 1912–13 cones.	May 8–May 31, 1914.	Breeding cage kept outdoors.
10884a	Ashland, Oreg.	Feb. 14, 1914	.....do.....	May 19, 1914; 1 adult.	Breeding cage kept in laboratory.
10890a	Hilt, Cal.....	Mar. 13, 1914	.....do.....	Apr. 20–May 20, 1914; 10 adults.	Do.

The egg gallery is usually kept straight and close to the axis of the cone. During the early part of the season it has frequently been observed that in the small cones, from 2 to 4 inches long, the adults extend the egg gallery nearly to the outer end of the cone, depositing four or five eggs along its length, and then bore out through the scales and emerge. It has not been determined whether such emerging adults attack another cone or not, but it is reasonable to assume that this is the case. In the larger cones, from 6 to 8 inches long, which are attacked later in the season, from 15 to 30 eggs may be deposited; and as this probably represents the minimum number of eggs deposited by a pair of beetles, it is evident that very short cones do not afford sufficient length of egg gallery for the deposition of this number. Consequently a pair of parent adults may extend the egg gallery through several of the smaller cones before the egg-gallery capacity of the cone is exhausted.

As the attack continues through the latter part of June, the size of the attacked cones keeps increasing until the larger ones are from 6 to 8 inches long. The parent adults seldom emerge from these larger cones and later in the season will be found dead in the end of the egg gallery. By the 1st of July the new attack is complete. At this stage the infested cones are from 2 to 8 inches long, while the normal unattacked ones are from 10 to 18 inches long. The blighted cones are brown and stand out conspicuously on the trees. The seeds seldom form when the smaller cones are attacked, whereas the seeds of the larger cones that are attacked may reach two-thirds normal size and the outer shell may harden, but they never fill or mature.

Immediately after hatching the young larvæ begin to feed upon the scales and tissues of the now withering cone. They feed in such a manner as to leave no distinct lateral larval galleries. If the cones are opened during the larval period the small white grubs may be found in any part of the cone, the axis, scales, and often in the tender milky seeds (Pl. II, fig. 3). The development of the larvæ is very rapid. Pupæ may be found in the cones within four weeks after the first attack. By the last of June the cones which contain pupæ are dry, withered, and reddish brown in color. At about this stage the dry, withered stalks begin to break from the limbs and the blighted cones fall to the ground. All sugar-pine cones which are attacked fall from the trees before the close of the season and the broods complete their development in these fallen cones. The pupæ transform to new adults, which begin to appear by July 10, and this transformation continues throughout the summer, until by the middle of August the majority of the broods have reached the stage of new adults. Practically all of the infested cones have fallen by this time and the brood remains in these cones through





FIGS. 1 AND 2.—SUGAR-PINE SEED TREES ON BURNED AREA NEAR COLESTIN, OREG.

Photographs were made in July, 1914. The area was burned in 1910, destroying all young growth and much of the mature timber. Although the trees have put on several good crops since that date, there are scarcely any sugar-pine seedlings on the area. The seed crops have been repeatedly attacked by the sugar-pine cone beetle. (Original.)

FIG. 3.—CONES ON GROUND UNDER SEED TREES.

The large opened cones are normal. The small cones have been killed by the cone beetle. (Original.)

WORK OF CONE BEETLES IN THE CONES OF SUGAR PINE.

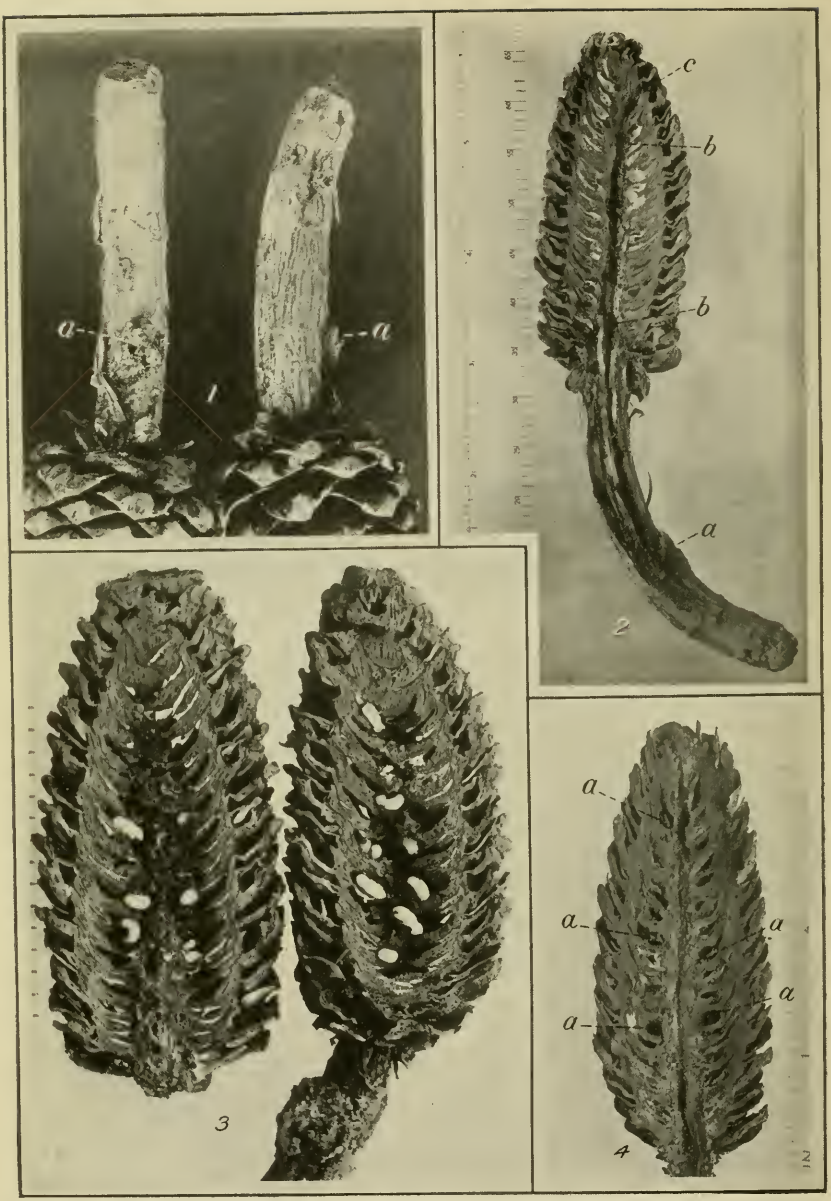


FIG. 1.—Showing stalks of beetle-killed sugar-pine cones after the cones have fallen from the tree: *a*, Entrance holes, showing small pitch tube made by beetle. FIG. 2.—A beetle-attacked sugar-pine cone opened to show tunnel and egg gallery of cone beetle: *a*, Entrace; *b*, egg gallery; *c*, extension of egg gallery to surface where adult emerges. FIG. 3.—Blighted sugar-pine cone opened to show developing broods of cone beetle. Larvæ and pupæ as found July 9, 1914. FIG. 4.—Blighted sugar-pine cone opened to show position of overwintering adults of cone beetle: *a*, Cone beetle adults. (Original.)

STAGES OF CONE BEETLES IN SUGAR-PINE CONES.

the remainder of the summer and the long overwintering period (Pl. II, fig. 4).

The new adults are not entirely dormant during this period, but feed to some extent on the dead tissue of the cone, as is apparent from the sawdust borings. The number of overwintering beetles which have been counted in a single cone varies from 1 to 36. The average, however, is from 6 to 10.

A considerable percentage of these blighted cones will always be found in which the beetles have made the attack and completed the egg gallery, but the larvæ have failed to develop. This failure of the broods is found more often in the very small and in the largest cones which have been attacked. The most successful attacks are found in the intermediate sized cones from 4 to 6 inches in length. Some of the larger cones appear to resist the beetles by drowning them out, as some trees are capable of resisting barkbeetles. In every attack, however, the cone is killed.

On certain areas great mortality to the new broods of the cone beetle, presumably through the work of an entomophagous fungus as yet not specifically determined, has been observed. In many of the cones the brood reaches the stage of full-grown larvæ, pupæ, or even new adults, and then dies. On an area near Sisson, Cal., in 1913, over 50 per cent of the cones contained these dead broods. On one area near Colestin, Oreg., in 1914, the brood developed in only 57 per cent of the attacked cones. The mortality of the developed broods amounted to 62 per cent, so the broods were finally successful in but 21.6 per cent of the cones attacked. The cause of this has not been determined and will require further study before conclusions can be drawn, although material illustrating the mortality of broods was sent in during the summer of 1914 and referred to the Bureau of Plant Industry. While it appeared to be an entomophagous fungus it has not yet been reported definitely. Few parasites of this cone beetle have been found.

All evidence points to the existence of but one generation of this species annually. The broods develop successfully only in the immature cones between $2\frac{1}{2}$ and 8 inches in length. The period during which the cones may be found in this stage is so short that it allows for the development of one generation only. In August, 1913, an emergence of a considerable portion of the new generation of beetles was noted in northern California and southern Oregon. No subsequent attacks were observed on the nearly mature cones of the 1913–14 crop or upon the newly formed 1913–14 cones. No similar emergence was observed in 1912 or 1914, and the only explanation that can be given for the 1913 emergence was that it was abnormal, probably due to the unusual wet-weather conditions of that season.

The actual amount of loss to sugar-pine seed crops from this source is not easily estimated. Even though a great portion of the crop may be killed, the seriousness of the loss depends upon local factors, such as the desirability of reproduction by the natural reseeding of the infested areas or the demand for seed by local seed collectors. A number of observations have been made from 1912 to 1914 in the vicinity of Ashland, Grants Pass, and Colestin, Oreg., and in California on the Klamath, Shasta, Trinity, California, Plumas, Sierra, and Sequoia National Forests and in the Yosemite and General Grant National Parks. These observations indicate that the sugar-pine cone beetle is distributed throughout the range of the sugar pine, killing a varying percentage of the cone crops. In some places no appreciable damage is found, while in others over 90 per cent of the cones are killed by this insect. Apparently, through a period of years, local outbreaks may occur in well-defined centers of infestation anywhere throughout the range.

RELATION OF CONE-BEETLE DAMAGE TO THAT OF SQUIRRELS.

The beetle-killed cones fall during a part of the period in which the sugar-pine cones are cut by squirrels. As these rodents are the cause of the cutting and falling of a great part of the cone crop, it is only natural that some of the damage caused by the cone beetle should have been attributed to the squirrel. For this reason considerable attention was given to a study of the comparative damage during the season of 1914 from these two causes.

The first cutting of the cones by squirrels in 1914 was noted on June 25 near Butte Falls, Oreg., and later in July at Colestin, Oreg. Extensive cutting by the rodents did not begin until the middle of July, and they were active from then until the end of summer. Two species, the gray and the Douglas squirrel, were noted in connection with this damage. Important differences, however, readily distinguish this damage from that of the cone beetle.

1. Squirrels cut the stalk just above the cone and a part of the stalk is left on the limb. (Pl. V, fig. 1.) The wound where the stalk is cut may also show teeth marks of the rodent. Cones which fall from cone-beetle attack have the entire stalk attached to the cone. There are no teeth marks; a small resinous pitch tube is usually found on the stalk. (Pl. II, fig. 1.)

2. Cones cut by squirrels are usually eaten or cached by them. Beetle-killed cones are allowed to lie on the ground where they fall and are unmolested by the squirrels.

3. The majority of the sugar-pine cones cut by the squirrels are 10 inches or more in length and the seeds usually full size, although they may still be soft and milky. The majority of the beetle-killed cones are less than 8 inches; some of them not over 2½ inches. By the time the cones fall the seeds are blighted or hollow.

In order to obtain definite figures on the comparative damage from these two sources, two localities were selected in southern Oregon where the 1913–14 crop of cones was fairly good. A number of trees were selected which were so situated that the cones falling from them would not become confused with those falling from other trees. A record was made at intervals of the good cones and of those infested by the beetle or cut by squirrels. The results are shown in Table II.

TABLE II.—*Comparative loss to sugar-pine cone crop of 1914 caused by the cone beetle and squirrels.*

AREA NO. 1, NEAR COLESTIN, OREG. RECORD OF COUNT ON FIVE TREES.

Tree No.	Date.	Cones on trees.		Cones on ground.[1]	
		Good.	Beetle attacked.	Beetle killed.	Squirrel cut.
1	July 18	0	3	51	2
	July 29	0	0	54	2
	Aug. 8	0	0	54	2
	Aug. 21	0	0	54	2
2	July 18	1	5	17	1
	July 29	1	0	22	1
	Aug. 8	1	0	22	1
	Aug. 21	1	0	22	1
3	July 18	8	13	27	14
	July 29	0	2	38	22
	Aug. 8	0	2	38	22
	Aug. 21	0	0	40	22
4	July 18	16	10	31	0
	July 29	8	0	41	8
	Aug. 8	5	0	41	11
	Aug. 21	0	0	41	18
5	July 18	8	68	83	0
	July 29	6	33	115	2
	Aug. 8	4	4	147	4
	Aug. 21	1	0	151	7

AREA NO. 2, NEAR ASHLAND, OREG. RECORD OF COUNT ON THREE TREES.

1	Apr. 30	33	0	0	[2] 0
	Aug. 11	1	0	0	32
	Aug. 27	0	0	0	33
2	Apr. 30	14	0	0	[2] 0
	Aug. 11	10	0	2	1
	Aug. 27	3	0	2	8
3	Apr. 30	68	0	0	[2] 0
	Aug. 11	65	1	0	2
	Aug. 27	20	1	0	47

[1] The beetle-killed and squirrel-cut cones found under the trees on the first date were collected and put together in a pile. Those found on the following dates were collected and added to these; so that, in the above table, the number of cones on the ground at each date represents the total number found up to and including that date.

[2] Cones about one-fourth grown.

This table shows fairly well the period and rate of falling of the beetle-infested cones. It also shows the great variation in the damage.

On area 1 about 85 per cent of the cones were destroyed by the beetles, while on area 2 the attack of the cone beetle was so slight as to be almost negligible.

The damage by the cone beetle was therefore practically accomplished before that by squirrels was started. On area 1 this re-

duced the food supply of the squirrels, so that by the middle of July, when the serious cutting by the squirrels began, there was very little of the crop left for them.

Many large sugar pines standing on prominent ridges where they could easily seed several acres of the slopes below have failed to accomplish this result. One area which the author has studied closely is situated just above Colestin, Oreg., where a heavy fire in 1910 killed most of the timber on several sections, although a number of large seed-producing sugar-pine trees distributed over the area were but little injured. (Pl. I, figs. 1, 2.) However, in 1914 scarcely any sugar-pine seedlings could be found near these trees. Evidence that this area has been heavily infested by the cone beetle since the fire is plentiful, and in 1914 it destroyed 75 per cent of the crop, the squirrels completing the damage as shown in Table II under area 1.

Either the cone beetle or squirrels, but more probably a combination of the two, is responsible for the absence of satisfactory reproduction in situations where it is much needed.

THE WESTERN YELLOW-PINE CONE BEETLE.

(*Conophthorus ponderosae* Hopk.)

The general life cycle of the cone-beetle broods in yellow pine does not differ in any important respect from that in sugar pine. The first attack on second-year cones has been noted to occur from two to three weeks earlier. The period of maximum emergence occurred from May 1 to 15 on two small lots observed. Close observations on the period of attack and development in this host were made near Ashland at elevations from 1,800 to 2,200 feet. This is from 1,500 to 2,000 feet lower than the elevations at which similar observations were made on the beetles in the sugar pine. The comparative difference in seasonal history as shown by these observations will be found in Table I.

The first attack of adults in 1914 was noted on May 5, but the adults were only just starting to bore into the cone and no egg gallery had been commenced. From May 10 to June 1 continued fresh attack was noted, and the latest fresh attack occurred on June 10. By June 3 the earliest attacked cones contained a few pupæ and were beginning to turn brown and wither, so that they could easily be distinguished from the normal green, unattacked cones. By June 15 pupæ and a few new adults were found in the cones first attacked and very little fresh attack was noted. The gradual transformation of the brood progressed through the latter part of June and the first part of July, and by July 15 new adults were infesting practically all cones.

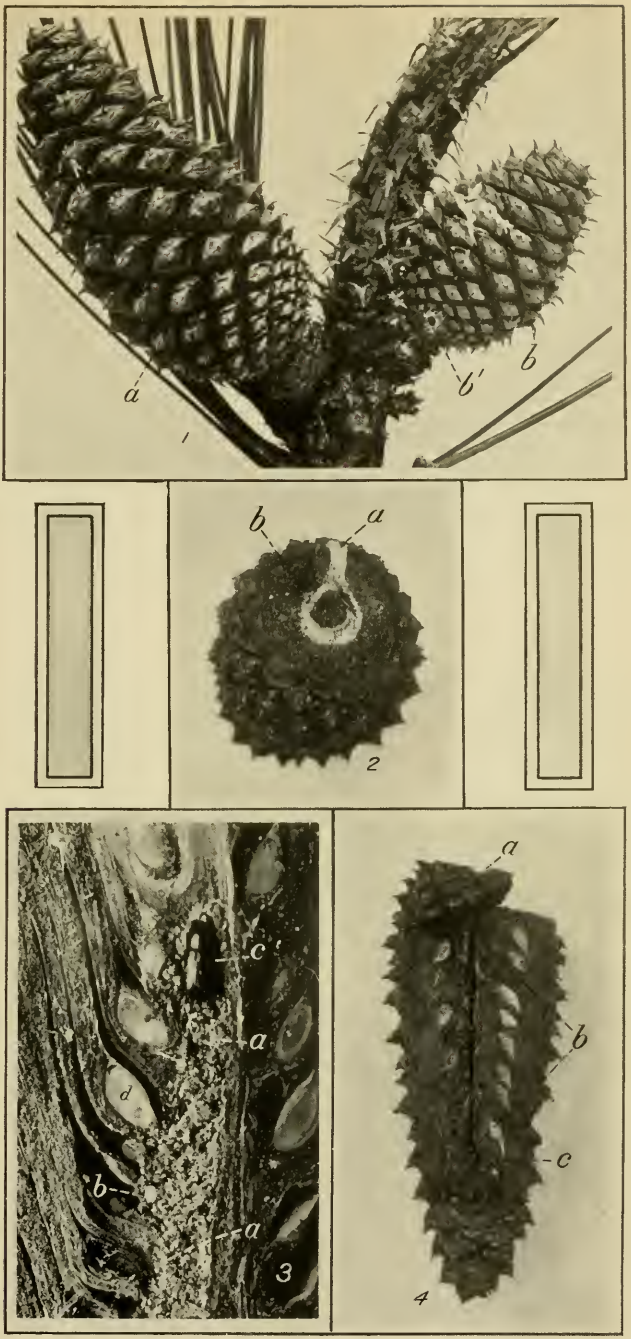
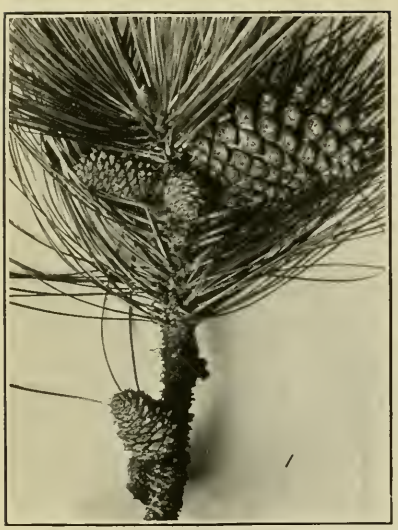


FIG. 1.—Yellow pine, showing condition of normal and blighted cone about 10 days after attack by the cone beetle: *a*, Normal cone; *b*, blighted cone; *b'*, entrance hole made by cone beetle. FIG. 2.—Blighted yellow-pine cone with part of base removed to show form of girdle made by the initial entrance of the cone beetle: *a*, Entrance; *b*, point at which the adult turned to extend the egg gallery into the axis of the cone. FIG. 3.—A portion of yellow-pine cone (near axis) opened to show egg gallery of the cone beetle, enlarged: *a*, Egg gallery, showing packed sawdust of beetle; *b*, egg; *c*, parent adult at terminus of egg gallery; *d*, immature seeds. FIG. 4.—Blighted yellow-pine cone with portion of base and scales removed to show the girdle made by the tunnel of the cone beetle and general form of the egg gallery: *a*, Entrance; *b*, egg gallery; *c*, parent adult. (Original.)

WORK OF CONE BEETLES IN CONES OF YELLOW PINE.



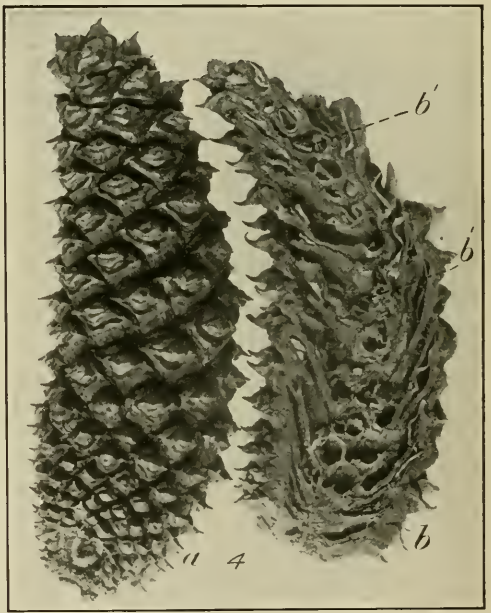


FIG. 1.—Blighted yellow-pine cones adhering to limb. This shows the position in which the majority of the yellow-pine cones are found. Near the terminal are shown three 1913-14 cones, two of them killed by the cone beetle. Farther back on the limb are the cones killed in 1912. FIG. 2.—A whorl of four yellow-pine cones, three of them killed by the cone beetle. The upper cone is normal. This shows the comparative size of the blighted and normal cones. FIG. 3.—A yellow-pine cone opened to show condition of developing brood of the cone beetle. This brood, on June 20, 1914, consisted of both larvæ and pupæ. (Slightly enlarged.) FIG. 4.—*a*, Blighted cone as it appears in overwintering condition; *b*, blighted cone opened to show damaged seeds and position of overwintering adults; *b'*, overwintering adults. (Original.)

WORK OF CONE BEETLES IN CONES OF YELLOW PINE.

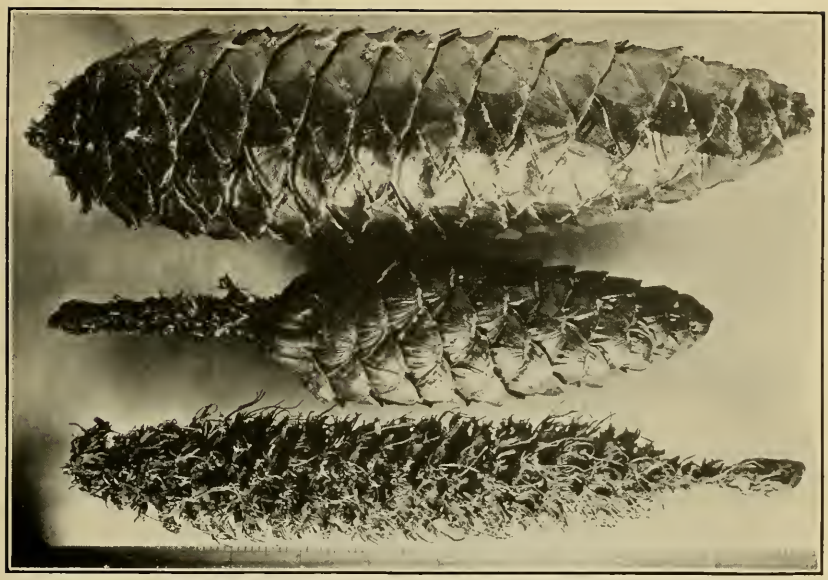


FIG. 1.—SUGAR-PINE CONES CUT BY SQUIRRELS.

The lower cone has been shucked and the seeds eaten. The cone in the center has been partly eaten. Note that the cones are cut at the base and do not have the stalk. Compare this with the blighted cones shown in Plate II, figure 1. (Original.)

FIG. 2.—YELLOW-PINE CONES CUT AND EATEN BY SQUIRRELS. (ORIGINAL.)

SQUIRREL DAMAGE TO PINE CONES FOR COMPARISON WITH THAT BY BEETLES.

Yellow-pine cones are sessile; that is, instead of being attached, each to its individual stalk, they are set closely to the limbs. At the beginning of the second-year growth they are from 1 to 1½ inches long. Necessarily the initial point of attack must differ from that on sugar-pine cones. The adult enters the cone by penetrating the scales very close to the base of the cone. Sawdust borings may be seen on the surface of the scales and quite often a tiny pitch tube collects around the entrance of the burrow (Pl. III, fig. 1*b*′). The adult does not turn directly outward through the central axis of the cone, but bores completely around the axis, forming a short spiral tunnel (Pl. III, fig. 2). This spiral twist of the tunnel before the beginning of the egg gallery is not noticeable in sugar pine, but it is characteristic of attack in yellow pine. Its result is completely to

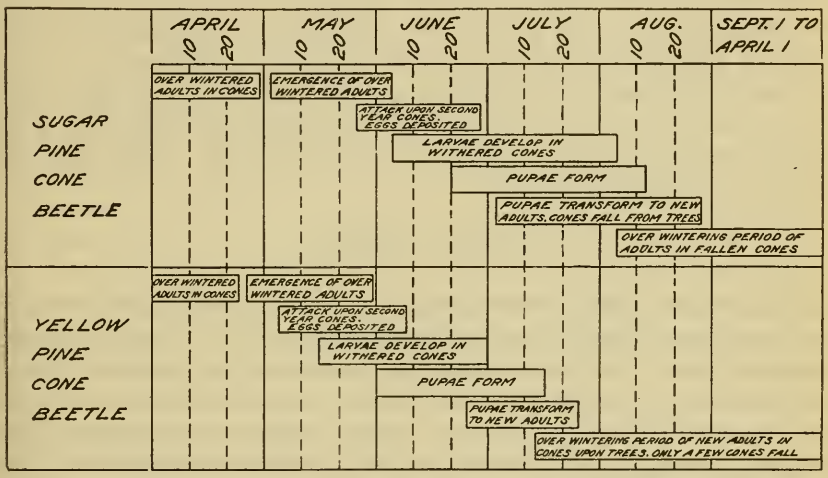


FIG. 1.—Comparative life history of the sugar-pine and yellow-pine cone beetles. Compiled from field records. (Original.)

cut off the nourishment and insure the deadening of the cone, which produces the condition necessary for the development of the larvæ. After completing this girdle at the base of the cone the adult extends the egg gallery out through the central axis (Pl. III, fig. 3). Oviposition (Pl. III, fig. 4), development of larvæ (Pl. IV, fig. 3), and transformation from pupæ to adults are in all important respects the same as with the sugar-pine cone beetle.

In a few instances attacks have been observed on the small, first-year cones just after they "put on." This seems to be a rare habit, and has only been observed where there is a great scarcity of second-year cones. Eggs are not deposited and broods can not develop in these small cones.

Beetle-killed yellow-pine cones vary from 1 to 4 inches, the length, as in sugar-pine cones, depending largely on the stage of second-year

growth when attack is made (Pl. IV, fig. 2). Yellow-pine cones, however, do not fall from the trees, and after they turn reddish brown in color they can be readily distinguished against the green foliage (Pl. IV, fig. 1). After the yellow-pine cones become dried they can not be broken readily from the limbs and quite often will be found still adhering many years after the beetles have abandoned them. The seeds may be formed, but they are invariably hollow in blighted cones (Pl. IV, fig. 4).

Occasionally a yellow-pine cone will be found that has been attacked by the beetle in which the new brood has failed to develop. The number of overwintering adults counted in the cones varied from 1 to 20, the average being from 5 to 8. The cone, however, is always killed and the damage is just as great.

The broods overwinter in the cones on the trees and emerge the following spring. (Pl. IV, fig. 4.) Adults do not appear to remain entirely dormant during this period, but feed to some extent on the dry scales and seeds. Mortality of the new broods, to any extent like that in the sugar pine, has not been observed. An examination of many infested cones of the 1913–14 crop shows that over 90 per cent of the new broods are alive.

AMOUNT OF DAMAGE.

The damage by the western yellow-pine cone beetle to yellow pine has never been noted to be as extensive as that of the species working in sugar pine. In heavy stands the loss to yellow pines is not so noticeable as it is on open isolated trees. Even in these isolated trees the amount of damage varies to a great extent on individual trees. Isolated trees at lower elevations, especially those bearing heavy cone crops, suffer most.

Two trees standing close together were selected and the cones counted as follows:

Tree No.	Green cones.	Beetle-killed cones.	Total.
1	515	448	963
2	700	65	765

The count was made August 5, 1914, at Ashland, Oreg. It shows how damage may vary with individual trees.

Estimates of the damage by this beetle necessarily depend upon the same factors as those pertaining to sugar pine. The damage, however, can not be confused with that of squirrels, as the beetle-killed yellow-pine cones adhere to the trees, while the squirrels invariably cut and either eat or cache the cones. (Pl. V, fig. 2.)

CONDITIONS REQUIRING CONTROL.

Since these insects are not a menace to growing timber, their control by direct expense is desirable only where it is found to be seriously interfering with the natural or artificial reproduction of the host tree. Under the conditions of the mature, well-stocked stands prevalent in the virgin forests of the West it is very doubtful whether the beetles ever interfere with the required natural reproduction to an extent sufficient to require artificial methods of control. Seldom is the entire crop killed and eventually through a period of years sufficient good seed is produced to replace the normal loss of trees from lightning, light fires, normal insect infestation, and overmaturity. However, conditions are entirely changed when the virgin forest has been destroyed by timber cutting, fire, or epidemic insect infestations. Yellow pine and sugar pine are rated as two of the most desirable timber species, and if the restocking of areas denuded of these species is to be accomplished by natural reproduction, full seed crops must be produced by the seed trees left on or near the areas. If the cone crops of such yellow and sugar-pine seed trees are repeatedly destroyed by the cone beetles, or if these infest them to such an extent that the destruction is completed by rodents, then the required seeding may be delayed until the ground is usurped by less valuable tree species. Under such conditions measures which will reduce the infestation of the beetle by direct expense may in the end effect a saving in the conservation of the forest. If burns or cut-over areas are restocked by artificial seeding the collection of sound, mature seed is necessary. Again, we may find that the cone beetles have so reduced the supply of cones on selected seed-collecting sites that seed can not be profitably collected. In the last case damage may be avoided by intelligent selection of noninfested seed-collecting areas. Or if the site is selected a year in advance, the infestation may be reduced and most of the seed crop saved by application of the remedy.

REMEDY.

From the discussion relating to the seasonal history of the insect it is obvious that from the last of August until the following May all the infestation within an area will consist of the broods of new adults which are overwintering within the blighted cones. It is evident that if fallen infested cones from the trees which seed in a burned or cut-over area can be raked up and burned between September 1 and May 1 a very appreciable reduction of the infestation and damage may result. In the case of sugar pine all infested cones

will be found on the ground under the trees during this period and, when the conditions seem to warrant it, burning may be done without great expense. September, October, and November would be the more favorable months for the work, as winter snow and unfavorable conditions for burning will probably be found during the winter and spring.

Seed collectors in locating areas for collecting may estimate the amount of cone-beetle damage on the trees by July 15—in some situations a month sooner—as the blighted cones by that time begin to stand out conspicuously on the trees. From these estimates the collector may determine whether or not the seed crop of the current year is too badly damaged to be profitably collected.

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DIV. INSECTS.

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 245

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER July 20, 1915.

FURTHER EXPERIMENTS IN THE DESTRUCTION OF FLY LARVÆ IN HORSE MANURE.

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INTRODUCTION.

The results reported in this bulletin are a continuation of the investigation dealt with in Bulletin No. 118, United States Department of Agriculture, inaugurated for the purpose of finding a substance that would destroy the larvæ of the house fly in their principal breeding place, namely, horse manure, without injuring the bacteria or reducing in any way the fertilizing value of the manure (Cook, Hutchison, and Scales, 1914). The work was conducted in cooperation by the Bureaus of Entomology, Chemistry, and Plant Industry at Arlington, Va., and New Orleans, La. The bacteriological work at New Orleans was done by Dr. William Seemann, dean of the Tulane School of Tropical Medicine, and thanks are due him for his cooperation. The entomological work at New Orleans was done by Mr. E. R. Barber, scientific assistant, Bureau of Entomology.

In Bulletin No. 118 it was suggested that manure be treated with borax immediately on removal from the barn in order to destroy the eggs and maggots of the house fly, and that borax be applied at the rate of 0.62 pound per 8 bushels, or 10 cubic feet, of manure. As large quantities of manure are used by truck growers, it was thought advisable to include in that bulletin a warning as to the possible injurious action of large applications of borax-treated manure on plants. For the same reason it seemed desirable to find some volatile or other organic substance which would be effective as a larvicide, but without possible toxic action on vegetation. Largely with this object in view, the investigation was continued during 1914. The larvicidal value of some inorganic substances was also tested.

Borax may be used with advantage for the treatment of outhouses, public dumps, and refuse piles of all kinds, cracks and crevices, floors of stables, and any accumulation of organic material which offers a

favorable place for the deposition of eggs. A treatment two or three times a week ought to suffice for all these cases except where large quantities of organic material are added, when the borax application should be made immediately, using the same quantity as in the treatment of horse manure. The best results are always obtained when the borax is applied in solution daily, as it is effective against the eggs and the maggots during their feeding period. (Table V, series 52, G and H.) Borax probably has no effect on the pupæ or adult flies.

GENERAL PLAN OF EXPERIMENTAL WORK.

CAGE EXPERIMENTS.

The plan of the work was the same as that outlined in Bulletin No. 118, and in addition a few experiments were carried out in concrete pits. New cages were constructed for the experiments at Arlington. In order to prevent the escape of larvæ by migration, the galvanized-iron pans in the cages in which the manure was placed were made 2 feet deep, and the small openings in the bottom of the pans through which the water drained off were covered with fine wire gauze. The legs were made 8 inches high to facilitate the removal of any larvæ which might get into the drip pans.

The manure was sprinkled in three layers by putting 2 bushels of manure in the cage and applying 2½ gallons of the solution. This was repeated in the second layer of 2 bushels. Finally the remaining 4 bushels were added and the last 5 gallons of the solution applied. When a chemical was applied in dry condition it was scattered over the surface of the manure, which was also treated in three layers, and 10 gallons of water were afterwards added. The manure in the control cages was sprinkled with water equal to the volume of the solutions used. The flies which were caught in the traps attached to the top of the cages were chloroformed and counted, and at the end of each experiment a comparison of the total number was made, and from these counts an index of the effectiveness of the chemical was obtained. Only fresh manure was used in the experiments, and every effort was made to provide for an even distribution of fly eggs and larvæ. That it was impossible to secure an equal infestation in all cages is evident from a comparison of the fly counts from the control cages.

OPEN-PILE EXPERIMENTS.

A few open-pile experiments were carried out at Arlington on the same plan as during the previous year. The most important open-pile experiments were conducted at New Orleans during November and December, 1914. In most of the New Orleans open-pile experiments 4 bushels of manure were sprinkled with 5 gallons of solution daily, and this was repeated four times, making a total pile of 16 bushels treated with 20 gallons of solution. The total number of

pupæ in each pile was counted about eight days after the last treatment. A sample of 200 pupæ from each pile was kept in the laboratory, and the percentage of emergence determined. From these data the apparent larvicidal effect was calculated. For some of the New Orleans experiments, cages (Pl. I, fig. 1, p. 16) were constructed to cover the piles, and instead of counting the number of pupæ the flies were allowed to emerge and were caught in traps attached to the tops of the cages. Temperatures and samples for analysis were taken through the armholes in the sides of the cages. Soil was banked against the base of the cages to prevent the escape of maggots and flies.

Chemical and bacteriological analyses were made of samples of manure from most of the cage and open-pile experiments.

SAMPLING FOR CHEMICAL AND BACTERIOLOGICAL ANALYSES.

It is very evident that a manure pile with the unequal distribution and great variation of its physical and chemical constituents will necessarily be exceedingly difficult to sample, especially to secure from it a few hundred grams which will be thoroughly representative. An attempt was made to secure representative samples by taking equal portions of manure from three different parts of the pile, spreading them on a clean sheet of paper, and finely dividing and thoroughly mixing them. When the material appeared quite uniform the sample was quartered. One quarter was then cut into half-centimeter lengths with clean shears. The straw or shavings were cut with the other material. When this operation was completed the sample was again thoroughly mixed. For chemical analysis the material was twice passed through a grinder. Both bacteriological and chemical examinations were made on the same sample. As the bacterial content of manure is very high, no attempt was made to work under absolutely sterile conditions, because the contamination arising from ordinary handling of the material was of no importance when compared with the great number of organisms present. However, precautions were taken to prevent excessive contamination by using clean paper, shears, etc., for each sample.

BACTERIOLOGICAL EXAMINATION.

Two 10-gram samples of the manure, prepared as just described, were taken for each bacteriological determination. One of the 10-gram samples was dried at 100° C. for one hour to determine the percentage of solids. The other sample was brushed into a 2-liter flask containing 1 liter of sterile water. The flask was then vigorously shaken for five minutes and again, after a five minute interval, for three minutes. A 1-c. c. sample was then withdrawn and run into 100 c. c. of sterile water. Five dilutions were prepared, ranging from 1 part in 10,000 to 1 part in 100,000,000. A duplicate series of Petri dishes was then prepared from these dilutions and standard beef agar.

After five days' incubation at 28 to 30° C. the plates were counted. The average counts of the duplicate plates were taken and converted into equivalents for 1 gram of dry manure by the use of the figures obtained from the duplicate 10-gram samples that had been dried at 100° C. The results obtained by plating on the standard beef agar are comparative and serve to show the germicidal action of the chemicals on the majority of the bacteria present in the manure. Dr. Seemann, in the work at New Orleans, used a medium prepared from manure water, but the counts were practically the same as those on beef agar.

CHEMICAL EXAMINATION.

The manure samples were analyzed for solids, ash, ammonia, and nitrogen, using the methods of the Association of Agricultural Chemists (Wiley, 1908). The total nitrogen determinations were made by the Nitrogen Laboratory of the Bureau of Chemistry. The results obtained by the magnesium-oxid distillation method for ammonia, which are not reported in the table, although much higher, showed the same general tendencies as the figures obtained on the water extracts.

Water extracts were prepared from each sample by taking 25 grams of the finely divided manure and adding 500 c. c. of distilled water, allowing them to stand for one hour, with occasional shaking. The solutions were filtered, and the following determinations were made: Water-soluble nitrogen, ammonia, nitrites, nitrates, and reaction.

Ammonia was extracted by the Folin and Macallum (1912) aeration method and nesslerized. Nitrites were determined with the sulphanilic acid reagent, and nitrates by the reduction method with aluminum foil (American Public Health Association, Laboratory Section, 1912). Nitrites and nitrates were not usually found in the samples examined, because the manure had not stood sufficiently long. The reaction was determined by taking 20 c. c. of the water extract, diluting with 200 c. c. of carbon-dioxid free water, and titrating with twentieth normal acid, using alizarin red as indicator.

GENERAL ACCOUNT OF SUBSTANCES USED.

Representatives of two groups of substances were tested during the season's work, namely, (1) inorganic and (2) organic, including volatile and nonvolatile substances and some plant material. These substances are arranged in alphabetical order in the respective groups.

INORGANIC SUBSTANCES.

Of the inorganic substances, arsenical dip, chlorid of lime, Epsom salts, lime-sulphur, and sulphuric acid in three concentrations were used.

ARSENICAL DIP.

Arsenical dip, which is extensively used in the West and Southwest to kill ticks on cattle and sheep, was prepared according to the directions given in U. S. Department of Agriculture Farmers' Bulletin No. 603 (Chapin, 1914). This solution was used in three cage experiments, namely, full strength, and diluted 1 to 1 and 1 to 3 (Table I, Series 67, A, B, and C).

TABLE I.—*Destruction of fly larvæ in horse manure. Results with arsenical dip, paradichlorobenzene, and pyridine; cage experiments at Arlington, Va., 1914.*

Series.	Treatment of 8 bushels of manure, using 10 gallons of liquid.	Flies emerged.	Apparent larvicidal effect.	Number of bacteria per 1 gram manure, calculated to dry weight.	Manure, total nitrogen.	Water extract.		
						Alkalinity, N/20 HCl per 100 c. c. (5 grams of manure).	Water-soluble nitrogen.	N as NH_3, Folin method.
		Number.	*Per cent of control average.*	*Millions.*	*Per cent.*	*C. c.*	*Per cent of total nitrogen.*	*Per cent of total nitrogen.*
67 A	Arsenical dip (strong).	67	87	1,648	0.421	10.50	33.63	3.5
67 B	Arsenical dip (1–1)	57	89	1,944	.337	5.75	29.97	4.4
67 C	Arsenical dip (1–3)	131	74	2,459	.547	6.50	33.82	3.7
70 A	Control (water only)	826	.....	1,636	.625	6.40	27.84	.....
70 B	.....do	382	.....	1,043	.463	8.75	41.25	7.1
70 C	.....do	275	.....	843	.337	8.40	26.70	4.7
	Control average	494	.....	.....	.....	.....	.....	.....
78 A	Pyridine, 1–100	37	63	634	.540	8.90	31.11	3.0
78 B	Pyridine, 1–500	135	0	798	.540	8.65	31.11	3.7
81 A	Control (water only)	53	.....	1,035	.611	9.90	26.68	1.9
81 B	.....do	252	.....	1,282	.639	11.15	36.93	2.4
81 C	.....do	96	.....	.....	.....	.....	.....	.....
	Control average	134	.....	.....	.....	.....	.....	.....
104 A	Pyridine, 1–100	3	99+	209	.470	4.75	28.72	7.02
104 B	.....do	2	99+	128	.449	4.50	33.85	2.45
106 A	Control (water only)	4,489	.....	19.6	.572	4.25	25.00	2.10
106 B	.....do	1,936	.....	27.1	.561	4.65	26.02	1.41
	Control average	3,212	.....	.....	.....	.....	.....	.....
79 A	Para-dichlorobenzene, ½ pound to 10 gallons water	10	93	905	.793	13.15	36.07	4.8
79 B	.....do	70	50	502	.505	11.65	35.44	4.6
	(For control see 81, A, B, and C, above.)							
98 A	Para-dichlorobenzene, 1 pound to 10 gallons water	11	97	.....	.....	.....	.....	.....
98 B	.....do	68	78	.....	.....	.....	.....	.....
99 A	Control (water only)	157	.....	283	.898	11.40	25.61	2.34
99 B	.....do	687	.....	165	.653	10.75	24.19	4.13
99 C	.....do	77	.....	157	.533	8.15	27.39	2.44
	Control average	307	.....	.....	.....	.....	.....	.....

The two stronger concentrations killed about 88 per cent of the maggots and the 1–3 solution about 75 per cent. The weaker strengths apparently exerted a slight stimulating action on the bacteria, and the full-strength dip showed no bactericidal action in this one test. The chemical data showed no marked differences except for the increased alkalinity where the dip was applied in full strength, and this, no doubt, was due to the sodium carbonate in the dip.

CHLORID OF LIME.

Chlorid of lime has been used extensively as a disinfectant and has been tested by Dr. Howard, who found that 1 pound applied to 8 quarts of manure killed practically all the larvæ, but one-fourth of a pound to 8 quarts was not sufficient (Howard, 1911). In our experiments with smaller amounts, namely three-fourths of a pound, 1½ pounds, and 3 pounds to 8 bushels and the addition of 10 gallons of water, negative results were obtained. The well-known action of chlorid of lime in driving off the ammonia from manure, the probable toxic effect on bacteria, and the irritating action of the liberated chlorin, as well as the high cost of the substance in quantities sufficient to kill fly larvæ, precludes its use for this purpose.

EPSOM SALTS.

Epsom salts was applied in three cage experiments, using respectively 1, 2, and 4 pounds to 10 gallons of water. In no case was any larvicidal effect noticed. No chemical or bacteriological examinations were made.

LIME-SULPHUR.

Lime-sulphur was used again this year in dilutions of 1 to 10, 1 to 20, and 1 to 30. No larvicidal effect was seen, and since it failed to kill the maggots, no chemical or bacteriological analyses were made.

SULPHURIC ACID.

Sulphuric acid was used in 1, 2, and 3 per cent solutions. Two cage experiments with each concentration were carried out. Practically no larvicidal effects were shown in any of the experiments. Sufficient alkaline substances and organic material were present in the manure to combine with the acid in the 1 per cent and 2 per cent solutions, consequently no injurious action on the bacteria resulted. No counts were made where the 3 per cent solutions were applied. When the 3 per cent applications were made the alkaline reaction of the manure was markedly reduced and the percentage of ammonia, in terms of the total nitrogen, was increased from three to four times that of the control. The 1 per cent and 2 per cent solutions had no apparent action on the manure as determined by the chemical results.

ORGANIC SUBSTANCES.

As the application to the soil of manure containing inorganic substances is likely to produce harmful effects on plants, due to a slight excess of the toxic element in the soil, it seemed desirable to investigate the larvicidal action of various organic substances, both volatile and nonvolatile. The volatile substances would produce

a true partial sterilization, as has been shown by several investigators (cf. Russel and Buddin, 1913, and the recent article by the latter, Buddin, 1914), while the nonvolatile substances would be finally decomposed in the soil, and, therefore, have no permanent injurious effect. Organic substances, when added to the soil, may be attacked by various members of the soil flora, as bacteria and filamentous fungi, which either destroy the substances entirely or form compounds that may be utilized by other organisms which are of value in maintaining the fertility of the soil or may be utilized directly by the plants themselves.

ANILINE.

Aniline ($C_6H_5NH_2$), which is extensively used in the preparation of dyes, contains 15 per cent of nitrogen and costs about 60 cents per quart. This substance was tested in cage experiments at Arlington, Va., using dilutions of 1 to 50, 1 to 100, and 1 to 200.

TABLE II.—*Destruction of fly larvæ in horse manure. Results with aniline and nitrobenzene; cage experiments, Arlington, Va., 1914.*

Series.	Treatment of 8 bushels of manure, using 10 gallons of liquid.	Flies emerged.	Apparent larvicidal effect.	Number of bacteria per 1 gram manure, calculated to dry weight.	Manure, total nitrogen.	Water extract.		
						Alkalinity, N/20 HCl per 100 c. c. (5 grams of manure).	Water-soluble nitrogen.	N as NH_3, Folin method.
		Number.	*Per cent of control average.*	*Millions.*	*Per cent.*	*C. c.*	*Per cent of total nitrogen.*	*Per cent of total nitrogen.*
94 A	Aniline, 1–50	4	98	264	0.526	8.25	41.63	7.98
94 B	Aniline, 1–100	11	97	392	.632	8.65	33.70	4.60
94 C	Aniline, 1–200	25	80					
99 A	Control (water only)	157		283	.898	11.40	25.61	2.34
99 B	do	687		165	.653	10.75	24.19	4.13
99 C	do	77		157	.533	8.15	27.39	2.44
	Control average	307						
100 A	Aniline, 1–200	17	99+		.618	4.15	25.08	1.40
100 B	do	28	99		.674	6.40	29.08	1.63
106 A	Control (water only)	4,489		19.6	.572	4.25	25.00	2.10
106 B	do	1,936		27.1	.561	4.65	26.02	1.41
	Control average	3,212						
95 A	Nitrobenzene emulsion (3¼ pounds nitrobenzene and ½ pound fish-oil soap to 10 gallons water)	0	100	551	.547	9.75	34.92	9.14
95 B	do	1	99+	667	.526	8.10	40.50	7.41
95 C	Same as foregoing, diluted 1–3	115	63					
99 A	Control (water only)	157		283	.898	11.40	25.61	2.34
99 B	do	687		165	.653	10.75	24.19	4.13
99 C	do	77		157	.533	8.15	27.39	2.44
	Control average	307						
101 A	Nitrobenzene (1.67 pounds nitrobenzene and ½ pound fish-oil soap to 10 gallons water) undiluted	4	99+		.565	6.40	34.69	8.32
101 B	do	0	100	323	.449	5.40	34.96	9.13
101 C	Same as foregoing, diluted, 1–1	5	99+					
106 A	Control (water only)	4,489		19.6	.572	4.25	25.00	2.10
106 B	do	1,936		27.1	.561	4.65	26.02	1.41
	Control average	3,212						

The results given in Table II show a 97 and 98 per cent larvicidal action with the two stronger solutions, and in the case of the 1 to 200 dilution two cages showed a 99 per cent and one an 80 per cent larvicidal action. The 1 to 50 and 1 to 100 strengths showed an increased number of bacteria. The amount of water-soluble nitrogen and ammonia is noticeably increased in the manure treated with the strongest solution of aniline, with no apparent action on the bacteria. The increases of the water-soluble nitrogen and ammonia are probably due to nitrogen in the aniline added. Aniline, among other substances, was tried in some cage experiments at New Orleans, the results of which are given in Table III.

TABLE III.—*Destruction of fly larvæ in horse manure. Results with aniline, hellebore, and nitrobenzene; cage experiments at New Orleans, La., 1914.*

Series.	Treatment of 8 bushels of manure, using 10 gallons of liquid.	Flies emerged.	Larvæ in drip pans.
		Number.	*Number.*
107 A	Aniline, 1–200	3,738	2,380
107 B	Aniline, 1–400	6,030	12,853
107 C	....do	5,070	9,856
108 A	Hellebore, ground, ½ pound to 10 gallons water	1,122	4,034
108 B	....do	820	4,567
108 C	Hellebore, ground, ¼ pound to 10 gallons water	1,130	1,285
108 D	....do	874	1,930
109 A	Nitrobenzene, 1 pound, and ½ pound fish-oil soap to 10 gallons water	3,390	2,985
109 B	....do	1,692	3,647
109 C	Nitrobenzene, ½ pound, and ¼ pound fish-oil soap to 10 gallons water	1,319	2,042
110 A	Control (water only)	1,085	560
110 B	....do	5,888	4,835
111 A	Aniline, 1–200	5,076	4,462
111 B	Aniline, 1–400	12,667	8,296
111 C	....do	12,309	19,675
112 A	Hellebore, ground, ½ pound to 10 gallons water	11,803	10,794
112 B	....do	17,197	8,179
112 C	Hellebore, ground, ¼ pound to 10 gallons water	20,067	9,315
112 D	....do	17,838	268
113 A	Nitrobenzene, 1 pound, and ½ pound fish-oil soap to 10 gallons water	2,395	10,132
113 B	....do	12	211
113 C	Nitrobenzene, ½ pound, and ¼ pound fish-oil soap to 10 gallons water	9,678	11,165
114 A	Control (water only)	19,366	11,419
114 B	....do	18,838	10,726

The cages were the ones used the previous year and, as the figures show, large numbers of larvæ escaped. Apparently these results show a low larvicidal effect of aniline, but since the condition of the cages was unsatisfactory they should not be compared with the others, especially as they are the only ones, either in cages or open piles, where poor results with aniline were obtained.

Open-pile experiments at New Orleans, using a 1 to 200 dilution of aniline, killed 85 and 99 per cent of the fly maggots (Table IV, series 46, A and B); 1 to 400 dilutions in two piles gave 79 and 83 per cent larvicidal effect (Table V, series 41, C and D); and two piles treated with aniline, 1 to 500, showed an 84 per cent destruction of larvæ (Table V, series 49, A and B).

TABLE IV.—*Destruction of fly larvæ in horse manure. Results with aniline, hellebore, nitrobenzene, and pyridine; open-pile experiments, New Orleans, La., 1914.*

Series.		Treatment: 5 gallons liquid to 4 bushels manure; 4 treatments each, except series 44 and 45.	Pupæ found.	Emergence from sample of 200 pupæ.	Apparent larvicidal effect.	No. of bacteria per 1 gram manure calculated to dry weight.	Manure.	Water extract.		
							Total nitrogen.	Alkalinity, N/20 HCl per 100 c. c. (5 grams of manure).	Water-soluble nitrogen.	N as NH_3, Folin method.
			Number.	*Per cent.*	*Per cent of control.*	*Millions.*	*Per cent.*	*C. c.*	*Per cent of total nitrogen.*	*Per cent of total nitrogen.*
144	A	Hellebore, ground, ½ pound to 10 gallons water	43,335		58.9	56.5	0.358	5.00	25.14	13.99
	B	....do	40,046		62.0	24.2	.421	4.75	28.02	7.84
	C	Hellebore, ground, ¼ pound to 10 gallons water	58,021		44.9	382	.379	5.50	31.14	13.98
	D	....do	77,056		26.8	1,170	.379	4.65	29.55	12.40
	E	Control (water only)	105,196				.386	5.00	26.16	15.54
145	A	Hellebore, ground, ⅛ pound to 10 gallons water	[2] 49,311		30.9	590	.400	4.00	15.50	7.50
	B	....do	[2] 41,148		42.3	1,940	.400	3.90	15.50	5.50
	C	Hellebore, ground, ¼ pound to 10 gallons water	[2] 60,107		15.9	1,000	.477	4.25	13.00	5.45
	D	....do	[2] 36,201		49.3	440	.435	4.15	14.25	8.28
	E	Control (water only)	[2] 71,305			880	.379	4.25	13.18	6.07
46	A	Aniline, 1–200	28,439	32.5	85.0	2,990	.407	6.00	41.28	16.21
	B	....do	6,460	13.5	99.4	77	.470	6.25	35.74	17.02
	C	Hellebore, ground, ⅜ pound to 10 gallons water	34,104	80.0	55.8	2,140	.456	4.75	29.60	11.18
	D	....do	56,718	37.0	66.0	1,150	.435	5.25	33.56	15.63
	E	Control (water only)	61,714	93.0		625	.407	5.25	38.57	16.46
47	A	Nitrobenzene, ¼ pound, and fish-oil soap, ½ pound, to 10 gallons water	4,140	62.5	89.4	1,240	.428	7.00	27.57	16.35
	B	....do	7,927	56.5	81.5	533	.351	5.25	25.64	10.25
	C	Hellebore, ground, ⅜ pound to 10 gallons water	13,770	53.0	70.0	967	.337	4.25	23.44	10.98
	D	....do	12,640	57.5	70.2	1,780	.442	4.25	20.36	7.92
	E	Control (water only)	24,312	95.5		2,750	.365	5.65	27.94	12.06
48	A	Pyridine, 1–1,500	122,907	82.5	8.3	484	.512	5.50	32.81	12.30
	B	....do	76,705	75.5	47.6	750	.491	7.25	34.22	15.27
	C	Hellebore, ground, ½ pound to 10 gallons water	49,602	84.0	62.4	1,780	.547	6.40	31.08	15.54
	D	....do	77,431	80.0	44.0	1,330	.449	4.90	47.44	7.80
	E	Control (water only)	110,470	96.5			.505	7.25	35.64	13.86
53	A	Hellebore, powdered, ½ pound to 10 gallons of water (alkaloids, 0.24 per cent) [3]	787	65.0	89.7	97.2	.393	5.65	30.00	7.89
	B	Hellebore, powdered, ½ pound to 10 gallons of water (alkaloids, 0.26 per cent) [3]	811	68.0	88.9	60.2	.400	3.90	22.50	10.00
	C	Hellebore, powdered, ½ pound to 10 gallons of water (alkaloids, 0.41 per cent) [3]	596	72.0	91.3	64.0	.400	6.25	26.75	11.75
	D	.....do [3]	965	60.0	88.3	97.0	.379	5.25	28.23	13.98
	E	Control (water only)	4,942	91.0		80.7	.400	4.25	25.25	12.50

[1] In series 44 and 45 there were 3 applications made; the first at the rate of 10 gallons to 8 bushels, the second and third at the rate of 5 gallons to 4 bushels.
[2] Number of flies emerged.
[3] Nitrites and nitrates present.

TABLE V.—*Destruction of fly larvæ in horse manure. Results with aniline, hellebore, nitrobenzene, and pyridine; open-pile experiments, New Orleans, La., 1914.*

Series.		Treatment: 5 gallons liquid added to 4 bushels of manure; 4 applications.	Pupæ found.	Emergence from sample of 200 pupæ.	Apparent larvicidal effect.
			Number.	*Per cent*	*Per cent of control.*
	A	Pyridine, 1-500	4,756		98.6
	B	....do	1,948		99+
41	C	Aniline, 1-400	70,642		79.4
	D	....do	56,651		83.5
	E	Control	342,771		
	A	Nitrobenzene, 1 pound and ½ pound fish-oil soap to 10 gallons water	96,053		75.0
	B	....do	92,771		76.0
42	C	Nitrobenzene, ½ pound and ¼ pound fish-oil soap to 10 gallons water	74,636		80.6
	D	....do	92,954		76.0
	E	Control	385,403		
	A	Hellebore, ground, ½ pound to 10 gallons water	564		99+
	B	....do	772		99+
43	C	Hellebore, ground, ¼ pound to 10 gallons water	13,265		95
	D	....do	17,526		93.7
	E	Control	273,520		
	A	Aniline, 1-500	1,707	67.0	84.2
	B	....do	1,603	74.0	83.6
49	C	Hellebore, powdered, ½ pound to 10 gallons water	502	52.0	96.4
	D	....do	162	43.0	99.0
	E	Control (water only)	7,202		
	A	Hellebore, powdered, ½ pound to 10 gallons water	398	49	97.8
	B	....do	293	49	98.4
50	C	....do	449	40.5	98.0
	D	....do	334	40.5	98.5
	E	Control (water only)	8,866	93	
	A	Hellebore, powdered, ½ pound to 10 gallons water	7	23.8	99+
	B	....do	14	23.8	99+
51	C	Hellebore, powdered, ¼ pound to 10 gallons water	12,294	71.0	80.0
	D	....do	24,233	71.0	60.0
	E	Control (water only)	43,733	95	
	A	Nitrobenzene, ¼ pound and 1 pound fish-oil soap to 10 gallons water	3,036	63	93.4
	B	....do	3,415	63	92.8
	C	Pyretheum, powdered, ½ pound to 10 gallons water	24,346	95.5	0
	D	....do	31,379	95.5	0
52	E	Hellebore, powdered, ⅜ pound to 10 gallons water	7,694	95	75.5
	F	....do	5,725	95	81.8
	G	Borax, powdered, 1 pound to 10 gallons water	1,390	8.5	99+
	H	....do	953	8.5	99+
	L	Control (water only)	29,831	98.5	

As only one duplicate set of open piles treated with aniline 1 to 200 was examined, the data are not sufficient on which to base any conclusion as to its effect on the bacteriological and chemical composition of the manure. Aniline in all open-pile experiments showed a high larvicidal efficiency even in the dilution of 1 to 500, but it should be handled with care because of its possible toxic effects.

BETA NAPHTHOL.

Beta naphthol was tried in three cage experiments, using solutions containing 0.1 pound, 0.33 pound, and 1 pound, respectively. Where the 1-pound application was made only 11 per cent of the maggots were killed, and in the other two cases the results were negative. No bacteriological or chemical examinations were made of the treated manure.

CRESYLIC ACID.

Cresylic acid, which is prepared from coal tar, was tried in dilutions of 1 to 20, 1 to 40, and 1 to 80 in cage experiments, but it was without action on the maggots. Bacteriological and chemical analyses were made of the manure treated with the 1 to 20 strength, and the bacteria were reduced 90 per cent. The alkalinity of the manure was reduced, and a slight increase in ammonia over that of the controls was found.

PARA-DICHLOROBENZENE.

Para-dichlorobenzene was employed in two sets of cage experiments, using one-half pound and 1 pound to 8 bushels of manure. The substance was ground and scattered over the manure, and water added. As shown (Table I, series 79, A and B, and 98, A and B), the apparent larvicidal effect varied greatly, the one-half pound strength indicating a 50 and 93 per cent action and the 1 pound indicating 78 and 97 per cent effectiveness. The bacterial counts and chemical analyses where the one-half pound applications were made showed only slight effects from this treatment. No analyses of the manure in the cages treated with the 1-pound applications were made. Para-dichlorobenzene was tried in one pit experiment. The pits were of concrete with inside measurements of 9 by 6 by 2 feet. Thirty-two bushels of manure were placed in the pits, and the manure in one pit was treated at the rate of 0.5 pound to 8 bushels. The other pit was untreated. From the former 403 flies emerged, and from the latter, 484. The larvicidal action was, therefore, apparently about 16 per cent. Duckett (1915) has found this substance to be an effective fumigant against various household insects and those affecting stored products.

FORMALDEHYDE.

Further experiments with formaldehyde were performed, using 1 to 6, 1 to 8, and 1 to 10 dilutions of the commercial 40 per cent formalin in water. The 1 to 8 and 1 to 10 strengths showed no larvicidal effects, and the action of the 1 to 6 solution on the maggots was slight (17 per cent). The bacteriological and chemical results showed the same general tendencies as those found last year, an increased number of bacteria and a reduction of the alkalinity being observed. As the cost of formaldehyde is high, and as strong solutions are required to kill the maggots, the use of this substance is not practical for this purpose.

NITROBENZENE.

Nitrobenzene ($C_6H_5NO_2$), commercially known as oil of mirbane, costs 20 cents per pound and contains 11.4 per cent of nitrogen. The vapors of this liquid are poisonous. Two sets of cage experiments at

Arlington were carried out with emulsions of this substance and fish-oil soap. The strength of these emulsions and the results obtained are given in Table II, series 95 and 101. The larvicidal results, with the exception of series 95, C, were good. The emulsions apparently produced a considerable increase in numbers of the bacteria. An increase of water-soluble nitrogen and ammonia was obtained in all the treated samples. Some further experiments at New Orleans, using the cages which were employed in 1913, gave poor results, as many larvæ escaped (Table III, series 109 and 113). The results of six open-pile experiments are recorded in Table V (series 42, A, B, C, and D, and 52, A and B), and the data for two additional open-pile experiments are given in Table IV (series 47, A and B). Bacteriological and chemical results are given in connection with the last two experiments. The duplicate samples indicate that there was a slight reduction in the number of bacteria and that there was no apparent effect on the manure as shown by the chemical data. All the experiments indicate satisfactory larvicidal results, but the best were those obtained with the largest quantity of fish-oil soap, namely, 1 pound (Table V, series 52, A and B), which killed 93 per cent of the larvæ. This fact suggests that the fish-oil soap is an important constituent of this larvicidal mixture.

OXALIC ACID.

Four cage experiments were carried out with oxalic acid, using 1 and 2 pounds to 10 gallons of water. One experiment with 1 pound gave negative larvicidal results, while the results from three experiments using 2 pounds were as follows: 3 per cent, 60 per cent, and 80 per cent. In the one sample of manure analyzed the bacterial count was reduced, and the ammonia was increased over the control.

PYRIDINE.

Pyridine (C_5H_5N), which is prepared commercially from coal tar, and is also obtained from the distillation of bone oil, is alkaline, contains 17.75 per cent nitrogen, and costs about $1 per pound. This liquid was used in three cage experiments in dilutions of 1 to 100 and in one cage experiment in a dilution of 1 to 500. The results of the cage experiments are shown in Table I (Series 78 and 104). The larvicidal efficiency of the 1 to 100 dilutions was 63 per cent for one cage and 99 per cent for the other two. The 1 to 500 dilutions showed no apparent effect. No consistent action on the bacteria is evident, and the water-soluble nitrogen and the ammonia from the treated samples are higher than from the controls.

In open-pile experiments at New Orleans (Table V, Series 41, A and B) pyridine 1 to 500 was used twice, giving an apparent larvicidal

effect of 99 per cent. Pyridine was used in two open-pile experiments in a dilution of 1 to 1,500 (Table IV, Series 48, A and B), and 8 and 47 per cent of the larvæ were killed.

It is impossible satisfactorily to explain the differences in the larvicidal efficiency of the pyridine in the cage and open-pile experiments where the 1 to 500 dilutions were employed. Different samples of pyridine were used in these two tests, and as the conditions are very different at Arlington and New Orleans the exact larvicidal value of the 1 to 500 dilutions is uncertain. As the 1 to 1,500 is the only dilution that is practical from a cost point of view and the larvicidal effect of this strength was low, this substance is hardly thought to be worthy of further consideration as a larvicide. The extremely disagreeable odor as well as the toxicity of pyridine makes its use in this work objectionable.

PLANT MATERIAL TESTED.

In looking for substances of an organic nature it seemed advisable to test material from several common plants and weeds, especial attention being given to those that are very abundant and therefore cheap.

Dr. Alsberg suggested the use of plants containing saponin, corn cockle being named as a waste product containing considerable amounts of this compound. Agave, a saponin-containing plant growing abundantly in Texas and Florida, was obtained by Mr. W. D. Hunter and was tried in two experiments. Other plant material, some of which contains alkaloids, were also included in the investigation, namely, "blackleaf 40" (an extract of tobacco), larkspur, hellebore, ox-eye daisy, pyrethrum, and stramonium.

Corn cockle.—Corn cockle (*Agrostemma githago*) is present in wheat screenings. The screenings used in this work contained about 43 per cent of corn cockle, and hæmolytic tests [1] showed the presence of considerable saponin. The screenings were ground and then extracted with water for 12 hours. Nine cage experiments at Arlington, using extracts of the screenings containing from 0.3 of a pound to 5 pounds per 10 gallons, were tried, and the highest apparent larvicidal action was 49 per cent. These results varied markedly, and in certain cases no larvicidal effect was obtained. Many bacteriological and chemical analyses showed no change in the number of organisms or the composition of the manure.

Agave.—The roots of several agave or soapweed plants (*Agave lecheguilla*) were macerated and water extracts prepared. Two and one-half pounds of the finely divided roots were extracted for 12

[1] The hæmolytic tests were made by Dr. C. S. Smith, of the Bureau of Chemistry.

hours in 10 gallons of water. This extract was used in two cage experiments and showed a larvicidal action of 82 and 84 per cent. The manure was unaffected chemically, and the bacterial count on one of these samples was considerably higher than the control counts.

"Blackleaf 40."—"Blackleaf 40," an extract of tobacco (*Nicotiana tabacum*), containing 40 per cent of nicotine sulphate, is used to a considerable extent as an insecticide, and it seemed worth while to test its effect on fly larvæ. It was tried in three cage experiments at Arlington, Va., diluted 1 to 50, 1 to 250, and 1 to 500. In none of these cases did it show any larvicidal action.

Larkspur.—Ground seeds of larkspur (Delphinium) were tested, using solutions prepared by treating 1 pound of the ground seeds with 10 gallons of 1 per cent sulphuric acid and allowing them to extract for 12 hours. The extract was applied undiluted, diluted 1 to 5, and diluted 1 to 15. The apparent larvicidal effect varied from 57 to 90 per cent. The bacteria were not affected by the application of the undiluted extract, and the only change in the manure noted was a decrease of alkalinity due to the acid present in the extract added.

Stramonium.—A sulphuric-acid extract of the ground leaves of stramonium (*Datura stramonium*) was prepared by mixing 1 pound of the ground dried leaves with 10 gallons of 1 per cent sulphuric acid and allowing this to stand for 12 hours. This extract was employed undiluted, diluted 1 to 5 and 1 to 15. The larvicidal results were not as satisfactory as those obtained above where larkspur extracts were employed. The bacterial count on manure treated with the undiluted extract was lowered somewhat, and the reaction showed a slight reduction in alkalinity due to the sulphuric acid present in the extract applied.

Hellebore.—Roots of hellebore (*Veratrum album* and *Veratrum viride*) were used both in a ground and in a powdered condition. As the following results will show, the powdered hellebore proved to be the more effective. Both 1 per cent sulphuric acid and water extracts of ground hellebore were used in cage experiments at Arlington (Table VI, Series 82, 92, 102, and 103), and the results indicate a high larvicidal action.

TABLE VI.—*Destruction of fly larvæ in horse manure. Results with ground hellebore; cage experiments, Arlington, Va., 1914.*

Series.	Treatment of 8 bushels of manure, using 10 gallons of liquid.	Flies emerged.	Apparent larvicidal effect.	Number of bacteria per 1 gram manure, calculated to dry weight.	Manure, total nitrogen.	Water extract.		
						Alkalinity, N/20 HCl per 100 c. c. (5 grams of manure).	Water-soluble nitrogen.	N as NH_3, Folin method.
		Number.	*Per cent of control average.*	*Millions.*	*Per cent.*	*C. c.*	*Per cent of total nitrogen.*	*Per cent of total nitrogen.*
82 A	Hellebore (ground), 1 pound to 10 gallons 1 per cent H_2SO_4, undiluted	10	94	423	0.526	7.15	27.76	2.85
82 B	Same as foregoing, diluted one-fifth	33	78	576	.688	10.25	24.42	2.76
87 A	Control (water only)	192	.....	506	.695	11.25	28.20	1.87
87 B	Do	114	.....	498	.618	15.40	27.18	2.59
87 C	Do	145	.....	.....	.....	.....	.....	.....
	Control average	150	.....	.....	.....	.....	.....	.....
92 A	Hellebore (ground), 1 pound to 10 gallons 1 per cent H_2SO_4, undiluted	35	89	.....	.456	7.50	27.19	2.63
92 B	Same as foregoing, diluted one-third	18	94.3	236	.470	6.15	23.83	3.40
93 A	Control (water only)	551	.....	29.8	.863	9.15	29.32	1.85
93 B	Do	333	.....	12	1.45	13.25	43.72	3.25
93 C	Do	67	.....	159	.905	14.15	31.05	2.87
	Control average	317	.....	.....	.....	.....	.....	.....
102 A	Hellebore (ground), ½ pound to 10 gallons 1 per cent H_2SO_4	315	90	.....	.526	(acid). 50	25.67	2.85
102 B	Do	267	92	.....	.498	(acid). 50	21.49	3.40
103 A	Hellebore (ground), ½ pound to 10 gallons water	58	98+	.....	.568	3.50	22.70	.....
103 B	Do	39	99	.....	.554	6.15	28.34	1.32
106 A	Control (water only)	4,489	.....	19.6	.572	4.25	25.00	2.10
106 B	Do	1,936	.....	27.1	.561	4.65	26.02	1.41
	Control average	3,212	.....	.....	.....	.....	.....	.....

The water extract proved to be just as satisfactory as the acid extract. Table III, series 108 and 112, shows additional results from some cage experiments at New Orleans, in which the effectiveness appeared to be very low, but the results are of doubtful value for the same reasons pointed out on page 8. It is very difficult to explain why so little larvicidal effect was found in series 112 in view of the uniformly good results in other cages and open piles.

Results from the application of water extracts of ground hellebore applied to open piles are shown in Table IV, series 44 to 48, inclusive. When used at the rate of one-fourth of a pound to 10 gallons, it had a variable larvicidal action, never above 50 per cent. At the rate of three-eighths of a pound to 10 gallons the results were, on the average, somewhat higher, but none was above 70 per cent; at the rate of one-half pound to 10 gallons series 44, A and B, Table IV, showed 59 and 62 per cent action; 48, C and D, showed 44 and 62 per cent; and Table V, series 43, A and B, showed 99 per cent effectiveness.

Powdered hellebore was used in several open-pile experiments at New Orleans, and the results, as shown in Tables IV and V, indicate that the application of one-half pound per 10 gallons was uniformly favorable, the percentages varying from 88 to 99, the average of 12 open-pile experiments being 95.5 per cent. With three-eighths or one-fourth pound of powdered hellebore to 10 gallons the larvicidal effects were lower but still showed considerable action. It is evident

that the larvicidal value varies with the amount of powdered hellebore used, but when applied at the rate of one-half pound or more to 8 bushels of manure it will be efficient. It is not known how hellebore acts as a larvicide. At present no information is available as to whether it has any effect on the eggs or pupæ of the house fly.

The effects of the presence of fly maggots in a pile of manure is very strikingly shown by comparing figures 2 and 3 of Plate I. The pile treated with hellebore has remained normal in shape and appearance (Pl. I, fig. 3), while the maggots have worked the untreated pile shown (Pl. I, fig. 2), the manure being finely divided and the pile scattered by the feeding and migration of the larvæ.

The bacterial counts of manure in the cages (Table VI) treated with 1 per cent sulphuric-acid extracts of hellebore showed no bactericidal effects.

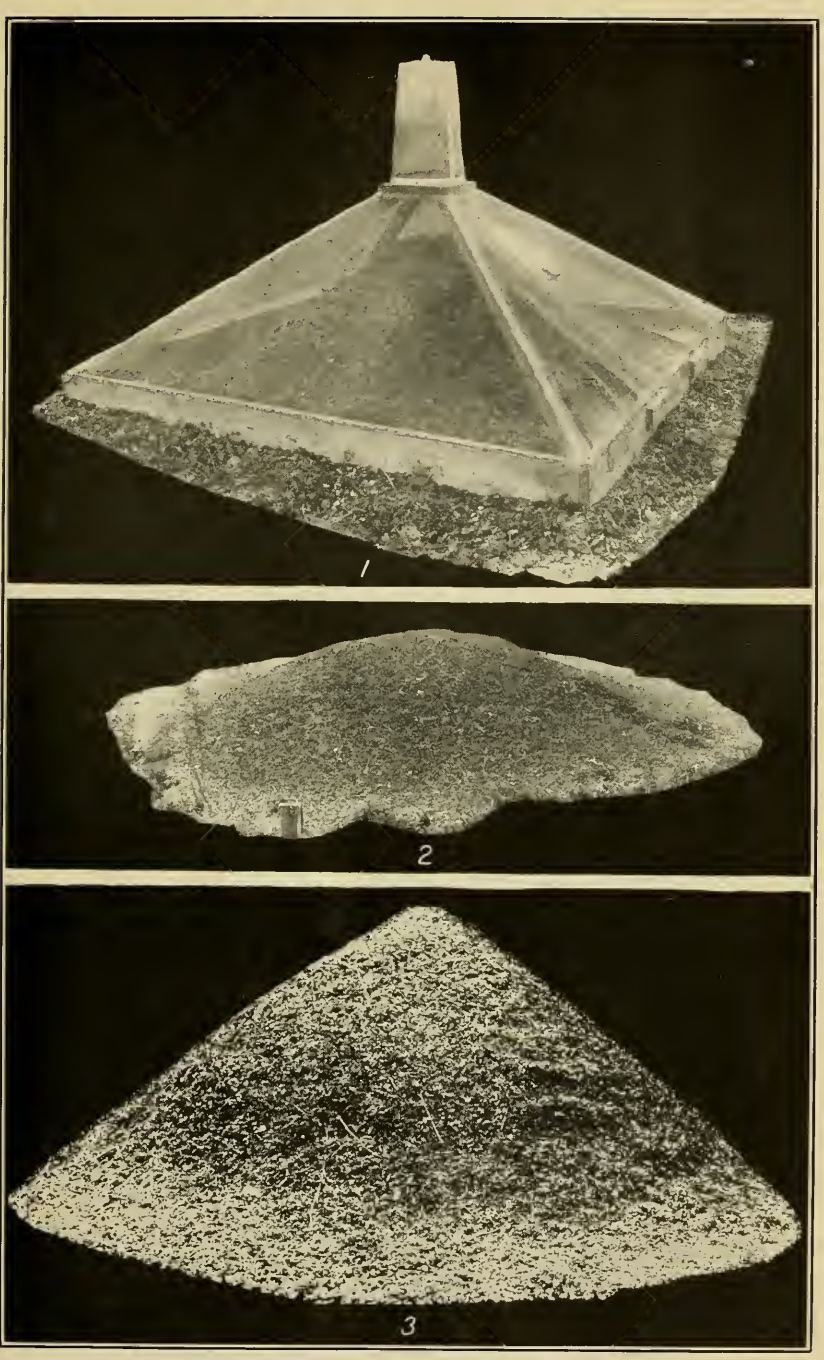
The bacterial counts of the open piles (Table IV) did not show any consistent action, either stimulating or bactericidal. During the season's work nitrites and nitrates were detected only in open-pile experiments 53, A, B, C, and D, which were treated with hellebore, and it is therefore apparent that the hellebore extract is not toxic to the nitrifying organisms in this environment.

Three series of temperatures taken daily of control piles and those treated with pyrethrum, pyridine, and hellebore further indicated that there was no permanent injury to the bacteria present in the piles treated with the last substance. In the first series the temperature was 13° below the control on the second day, but on the third day was again the same as the control. Neither of the other series showed any depression of temperature at the start, and the piles seemed to undergo a normal fermentation, indicating, as do all the data, that the treatment with hellebore does not reduce the fertilizing value of the manure.

The chemical data on both the cage and open-pile experiments show that the manure was unaffected by the hellebore treatment. When 1 per cent sulphuric-acid extracts were used in the cage experiments at Arlington, a reduction in alkalinity due to the added acid was found. It is, therefore, evident that powdered hellebore can be applied, using one-half pound to 10 gallons of water, without injuring the fertilizing value of manure as determined by chemical and bacteriological examination. Furthermore, a laboratory test has shown that hellebore readily decomposes in manure. A sample of manure treated with hellebore at the rate of one-half pound per 8 bushels when tested microscopically and colorimetrically gave positive results, but after 30 days' fermentation both were negative.

The alkaloidal content of the commercial green and white hellebore is known to vary from about 0.2 per cent to 0.9 per cent of total alkaloids.[1] In Table IV, series 53, the hellebore used was of known

[1] Data obtained from Insecticide Laboratory, Bureau of Chemistry, U. S. Department of Agriculture.



DESTRUCTION OF FLY LARVÆ IN HORSE MANURE.

FIG. 1.—Type of cage used for catching flies from treated manure piles. FIG. 2.—Settled and finely divided condition of an untreated pile, heavily infested with maggots. FIG. 3.—A hellebore-treated pile of same source and volume as figure 2. Hellebore, by preventing growth of fly maggots, prevented the disintegration of the heap. (Original.)

alkaloidal content; the two samples contained 0.25 and 0.41 per cent, respectively, and no differences in larvicidal action were evident.

The powdered hellebore used in the other experiments at New Orleans contained 11.49 per cent of ash, 1.04 per cent of total nitrogen, and about 0.2 per cent of total alkaloids. The ground hellebore used contained 29.39 per cent of ash, 1.08 per cent total nitrogen, and 0.2 per cent total alkaloids. It is therefore likely that commercial powdered hellebore of reasonable purity will be effective as a larvicide if applied as directed (p. 19).

General discussion of hellebore.—There are three plants which are popularly called hellebore, namely, *Veratrum album*, *Veratrum viride*, and *Helleborus niger*. The term "hellebore" is correctly applied only to *Helleborus niger*, which grows in Europe and is not at the present time a commercial product in this country. The white and the green are the two commercial varieties, the white being largely imported, and the green the American plant. For insecticidal work these two varieties are considered equally valuable. The American hellebore (*Veratrum viride*), called "swamp hellebore," "Indian poke," and "itch-weed," is a common plant in wet ground and grows over a considerable area of the United States. The properties of this plant are said to be similar to those of white hellebore. A number of alkaloids are claimed to have been separated from these two plants, but there is some uncertainty as to their identity and activity. Powdered hellebore, both the white and the green, is extensively used as an insecticide against the currant worm and to kill various insects around the roots of plants. Both varieties of hellebore are used in medicine to some extent.

OTHER PLANT MATERIAL.

Oxeye daisy.—Tests were made with the ground flowers of the oxeye daisy (*Chrysanthemum leucanthemum*), using 1 pound to 10 gallons of 1 per cent sulphuric acid. The material was extracted for 12 hours, and the extract was used undiluted and diluted 1 to 5. The larvicidal results were practically negative in both cases, but as the manure used in this experiment was lightly infested with larvæ and the results hardly warrant any definite conclusions. Bacteriological and chemical examinations were made of the manure treated with the undiluted extract. The bacterial count of the manure was somewhat lower than the controls, while the only noticeable change in chemical composition was a decrease in the alkalinity due to the acid in the extract added. The oxeye daisy contains a volatile oil but no alkaloid has been found.

Pyrethrum.—Pyrethrum (*Crysanthemum cinerariaefolium*) powder was tried and two results from open-pile tests at New Orleans show that solutions containing 0.5 pound per 10 gallons of water had no larvicidal action (Table V, series 52, C and D). Pyrethrum contains a volatile oil, and an alkaloid has been detected by one or two investigators.

DISCUSSION OF DIAGRAM (FIG. 1).

From the results of some open-pile experiments at New Orleans the comparative cost and larvicidal efficiency of some of the more favor-

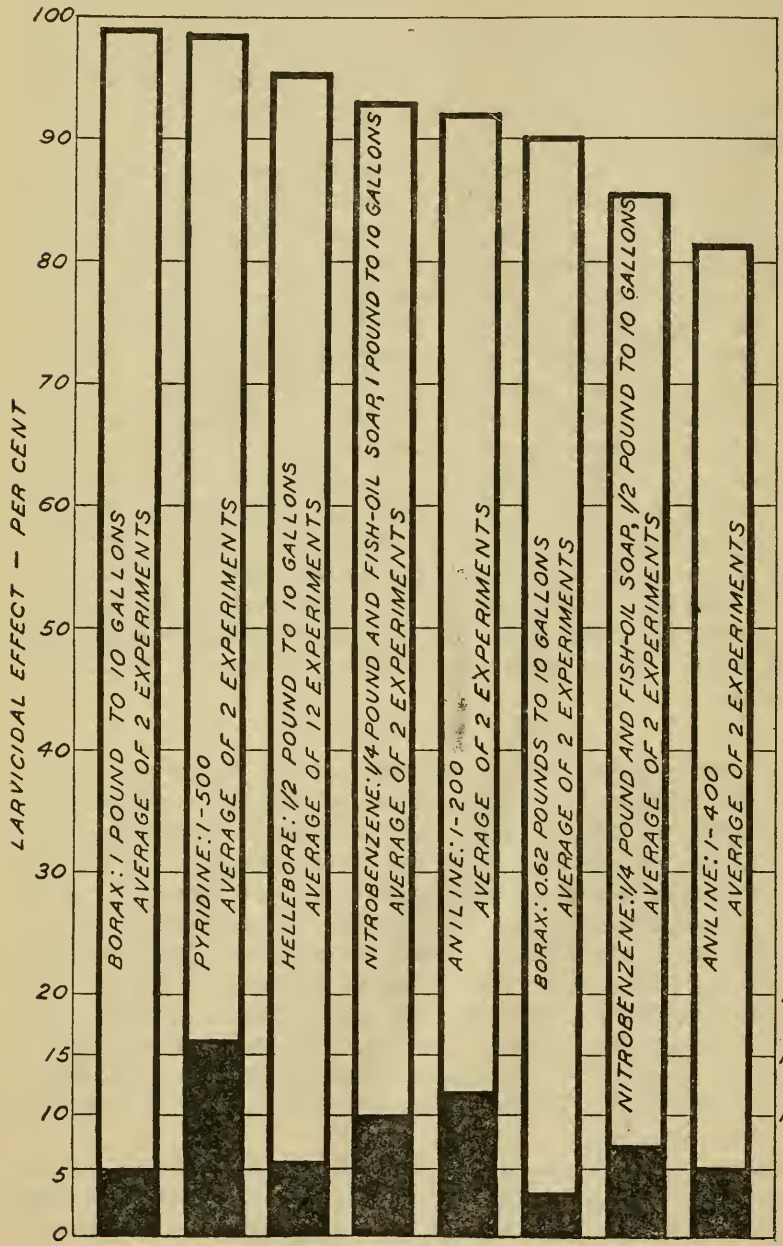


FIG. 1.—Diagram showing larvicidal effect and comparative cost of the treatment of 8 bushels of manure by various chemicals. (Original.)

able substances have been computed and are shown graphically in figure 1. Most of these calculations are based on an average of but

two experiments and are therefore to be regarded as only tentative. However, the results of the cage experiments are in general agreement with the findings as given in the diagram.

It will be noted that the highest larvicidal effect was obtained with borax, using 1 pound to 8 bushels. The least expensive treatment was that with 0.62 pound of borax, although the larvicidal action was only 90 per cent. The next cheapest was hellebore, which costs 5½ cents for one-half pound of the powdered roots, and the average of 12 experiments showed a larvicidal action of 95.5 per cent. The hellebore treatment at the foregoing rate costs more than that with 0.62 of a pound of borax but shows a greater efficiency.

In comparing the cost we have assumed that borax can be obtained at 5 to 6 cents per pound in 100-pound lots and that hellebore can be purchased at 11 cents per pound in like amounts. The price of both is subject to considerable variation. The results in general indicate that the larvicidal action varies with the amounts used, except in the case of nitrobenzene, where the value seems to depend on the proportions of nitrobenzene and soap in the emulsion.

It will be noted that pyridine and aniline, when used in amounts sufficient to kill a high percentage of the larvæ, are quite expensive, and for this reason their use can not be considered practical.

APPLICATION OF HELLEBORE TO MANURE.

Powdered hellebore should be mixed with water at the rate of one-half pound to 10 gallons and the solution thoroughly stirred and allowed to stand for several hours in a barrel or other container. In order to obtain the most satisfactory results, the manure should be sprinkled with the foregoing solution immediately on removal from the barn. The sprinkling may be done with a watering can or similar device, using 10 gallons to 8 bushels of manure, taking care that all of the hellebore comes in contact with the manure and paying particular attention to the outer edges of the pile. In estimating the amount of solution to be employed it may be assumed that 2 bushels of manure per horse is the daily output of the stable. This is a liberal estimate, and in many stables the daily output is much less.

EFFECT OF HELLEBORE ON PLANTS AND CHICKENS.

During November, 1914, a series of tests was started at both Baton Rouge and New Orleans, La., to determine whether hellebore, when applied in considerable amounts, exerts injurious effects on plant growth. The plants grown included cabbage, lettuce, oats, turnips, radishes, potatoes, wheat, and mustard, half of each plat being fertilized with hellebore-treated manure, and the other half receiving untreated manure. At the present time no injurious

effect is noticeable from the experiments at either New Orleans or Baton Rouge.

The cooperation of Mr. George L. Tiebout, of the Louisiana Experiment Station, Baton Rouge, and of Mr. W. G. Taggart, of the Audubon Park Sugar Station, New Orleans, in connection with these tests was of great assistance.

As chickens and other farm animals are known to peck at, or consume, certain parts of manure, tests were made by Mr. E. R. Barber, placing hellebore-treated manure in coops with chickens and using as controls chickens in a coop with untreated manure. Thirty-eight one-hundredths of a pound of powdered hellebore was mixed with 4 bushels of manure and placed in one coop with four chickens, and every three days another lot of the manure similarly treated was placed in this coop. The manure which was used contained fly maggots, consequently the chickens were eager to peck through it. In addition, the chickens, in both cases, were fed on cracked corn and were given fresh water. The appearance of the chickens was noted daily, and the test has been conducted for several weeks with no apparent ill effect due to hellebore.

SUMMARY.

The larvicidal efficiency of both inorganic and organic substances was tested and bacteriological and chemical examinations of horse manure to which many of these substances were applied are reported.

The following inorganic substances were tried:

Arsenical dip.
Chlorid of lime.
Epsom salts.
Lime-sulphur.
Sulphuric acid.

Of these substances arsenical dip was the only one which when used in amounts considered practical destroyed the larvæ of the house fly. Because of its poisonous nature the use of arsenical dip as a larvicide is not recommended.

The following organic substances were tested:

Aniline.
Beta-naphthol.
Cresylic acid.
Para-dichlorobenzene.
Formaldehyde.
Nitrobenzene.
Oxalic acid.
Pyridine.

Aniline, pyridine, and nitrobenzene, when used in certain dilutions, gave satisfactory larvicidal results, but the cost precludes their use.

The larvicidal action of the following plant materials was tested:

Plant material containing saponin—

Corn cockle (*Agrostemma githago*).
Agave (*Agave lecheguilla*).

Plant material containing alkaloids—

"Black leaf 40"—tobacco extract (*Nicotiana tabacum*).
Larkspur (Delphinium).
Stramonium (*Datura stramonium*).
Hellebore (*Veratrum album* and *Veratrum viride*).

Other plant material—

Oxeye daisy (*Chrysanthemum leucanthemum*).
Pyrethrum (*Chrysanthemum cinerariaefolium*).

Powdered hellebore proved the most efficient and practical of all the substances tested.

COMPARATIVE ADVANTAGES OF BORAX AND HELLEBORE.

Borax, which was shown in Bulletin No. 118 to be an effective larvicide, is obtainable in all parts of the country, and the cost of treating manure at the rate of 0.62 pound of borax per 8 bushels is 0.42 cent per bushel.

Powdered hellebore, using one-half pound to 10 gallons of water and applying this to 8 bushels of manure, is also an effective larvicide and exerts no injurious action on the fertilizing value of the manure as determined by bacteriological and chemical analyses, and no injurious action on plants has been detected in any of the field tests. Hellebore is used as an insecticide and is obtainable in most cities and agricultural districts. The cost of this treatment is 0.69 cent per bushel of manure.

While borax may be applied to manure at the foregoing rate and the treated manure may be added to the soil at the rate of 15 tons to the acre without injuring vegetation, nevertheless excessive quantities of borax may be applied to manure through carelessness, and injury to vegetation may in consequence result. In the light of this year's experiments it seems advisable to recommend borax as a larvicide for the treatment of outhouses, refuse piles, and all other places where flies may deposit eggs. However, on account of the possible carelessness previously mentioned, and because large quantities of manure are sometimes used by truck growers, it seems best to guard against possible injury to vegetation by recommending powdered hellebore for the treatment of manure, since no injury can arise from the use of excessive quantities, as it is entirely decomposed in the course of the fermentation of the manure.

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SECTS.

UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 248

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. ▼ August 14, 1915

FLEAS

By

F. C. BISHOPP, Entomological Assistant, Southern Field Crop Insect Investigations

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INTRODUCTION.

Fleas have forced themselves on man's attention for many centuries. All are familiar with these elusive little pests, knowing well their brownish color, peculiar flattened shape, apparent ability to sense the approach of danger, and the proverbial ease with which they escape. Their propensities for annoying man by inflicting bites in rapidly changing situations and for persistently worrying dogs and cats are well known.

However, it is not only in the rôle of annoyers of man or beast that fleas assume importance, for within the last decade the world has come to know fleas in their most important relationship to the welfare of mankind—that of transmitters of disease, and particularly of the dread disease known as plague. Aside from plague, which levies a death toll well into the hundreds of thousands yearly, attention is directed to fleas as important insects on account of their probable

NOTE.—The activities of fleas as carriers of bubonic plague and other diseases, as parasites upon poultry, and as pests to man and other animals are presented in this bulletin. Descriptions, life history, breeding places, hosts, and methods of eradication and control are given.

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connection with the disease of warm climates known as infantile kala-azar. There is also reason to believe that fleas play some part in transmitting leprosy. It has been found that the tapeworm of the dog, which has been known to attack man, is dependent upon some insect in which to develop one of its stages, and the dog flea often serves in this capacity. Another interesting rôle which a certain species of flea has been found to fill, though of no known direct importance to man, is the transmission of a blood parasite of the rat known scientifically as *Trypanosoma lewisi*. One kind of flea which is becoming widely distributed in the Tropics has the peculiar habit of burrowing into the flesh of man, especially around the toes. This species causes severe sores and often permanent crippling. In the United States, aside from their connection with plague transmission, we are concerned most with insects of this group as annoyers of man and animals. In the latter case the pests often become so numerous as to cause more or less loss. This is particularly true of the chicken flea, or "sticktight," which will be discussed in the following pages.

Fleas, as is generally known, are true insects. They have been thought by many entomologists to be closely related to the Diptera, or two-winged flies, but now they are usually considered to constitute a separate order of insects. Their peculiar shape,[1] flattened from side to side, and armature of spines and bristles are closely correlated with their parasitic habits, enabling them to move rapidly between the hairs or feathers of their hosts.

HOSTS OF FLEAS.

Fleas in the adult stage may be said to be parasitic exclusively on warm-blooded animals. A single exception has been recorded—that of one flea which was found attached to a land snake in Australia.

A great many species of birds and most mammals have been found to be infested by these parasites. The group of animals of which the horse, ox, and sheep are representative are probably least subject to attack. It is not the purpose to convey the idea that there are as many kinds of fleas as there are birds and animals. In fact, the number of distinct species of fleas now known is probably not greatly in excess of 400. In general, there are certain birds or animals, spoken of as hosts, upon which these insects prefer to feed.

Some species of fleas appear to have much more restricted host relationships than others; that is, they are found on comparatively fewer animals. In other instances fleas may not be found uncom-

[1] Some knowledge of the structure of a few of our common kinds of fleas may be derived from an examination of the illustrations in the following pages, which, with the exception of figure 1, were drawn by Mr. Harry B. Bradford.

monly on certain hosts, but they are not at home on these and would probably not live long or reproduce if made to feed on them exclusively. This class of hosts usually becomes infested by being closely associated with the true host of the fleas, as, for instance, in case of a rat entering a squirrel burrow or a carnivorous animal devouring a flea-infested rodent and thus getting the insects upon its body. Such hosts are usually spoken of as accidental or temporary. While infestations of this kind are seldom of importance to the host animal from the standpoint of direct injury, they may have a vital influence by transmitting disease and may also have an important bearing on control. As a result of this habit of fleas of clinging to, or temporarily feeding on, hosts which are not necessarily congenial, long lists of species of fleas accredited to a single kind of animal or bird are often found. For instance, more than 20 species of fleas have been taken on common wharf rats.

BITING HABITS.

The sensation produced by the biting of a flea is well known to most persons. The annoyance, however, is partly produced by the movements of the insect and by the mental unrest caused by the knowledge that fleas are present beneath the clothing. The effect of flea bites on man is discussed further on page 16. With very rare exceptions, adult fleas partake of no food other than the blood of warm-blooded animals, and it appears that reproduction never takes place until the fleas have partaken of such blood.

The mouth parts are well adapted to piercing the skins of their hosts and sucking up the blood. The essential piercing organ consists of three slender parts. A groove along the inner sides of two of these, the mandibles, with the closely applied third, forms a channel through which the salivary fluid is forced into the wound and through which the blood is pumped into the body. An idea of the structure of the mouth parts may be gained by referring to figure 1, *e* and *g*.

Most species are easily disturbed when feeding, and this accounts, in part at least, for the frequency with which a single flea may bite.

With the exception of the "sticktight" flea and certain of its relatives, fleas do not remain attached to their hosts for long periods. The amount of time spent off the hosts seems to vary much with the species. Normally the adults feed every day and possibly oftener, but in the case of interrupted meals, as has been mentioned, they may bite a great many times during a day, and some species, such as the cat and dog fleas, probably remain on the host almost continuously, feeding at very frequent intervals. A great many fleas are nocturnal. These

depend largely on finding a host at night, and they tend to keep secluded during the day.

In the case of inoculation of an animal with plague bacilli by a flea it has been observed that there is a relationship between the point of flea attack and the formation of the sweelings, or buboes. In this connection it is interesting to note that certain species show a marked tendency to infest certain portions of the host animal.

LIFE HISTORY.

The fleas pass through four distinct stages of development, viz, the egg, the larva, the pupa or resting stage, and the adult. All of

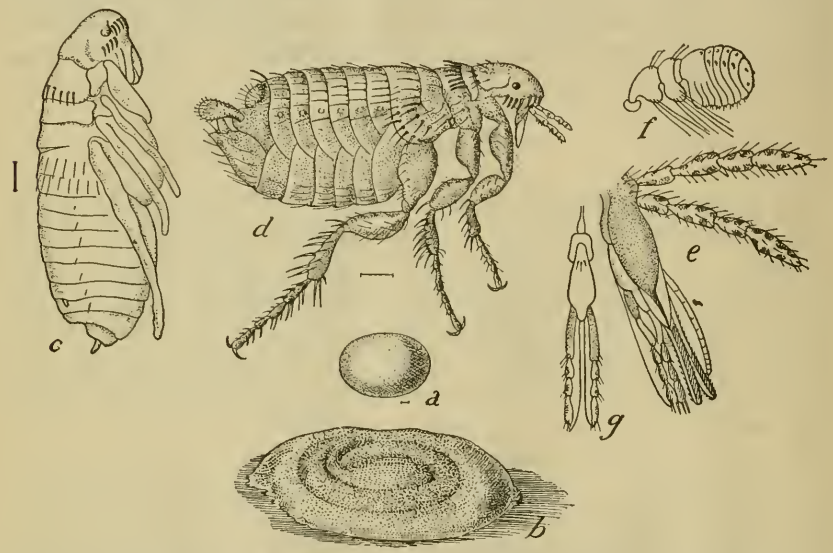

FIG. 1.—The dog flea (*Ctenocephalus canis*): *a*, Egg; *b*, larva in cocoon; *c*, pupa; *d*, adult; *e*, mouth parts of same from side; *f*, antenna; *g*, labium from below. *b*, *c*, *d*, Much enlarged; *a*, *e*, *f*, *g*, more enlarged. (From Howard.)

the different kinds of fleas resemble one another rather closely in these different stages.

THE EGG.

The eggs are ovoid in shape and white or creamy in color, some strongly reminding one of miniature china eggs. Although rather small, they are readily seen with the naked eye, especially if placed on a dark piece of cloth or paper. (Fig. 1, *a*.) They are formed after the female has been feeding on a host for a few days and are usually deposited while the flea is on the host, but are not glued to the hairs or feathers, as is the case with lice and some other insects. The human flea probably deposits most of its eggs while free from the host. The eggs usually fall from the animals in their nests; hence

there is a tendency for the young and, of course, the resulting adults to concentrate in the vicinity of the sleeping places and most frequented haunts of the host. This serves the fleas in three ways: (1) By giving them the protection of the bed of the animal in which to develop; (2) by furnishing food to the young in the form of partly digested blood excreted by the adults while on the host; (3) by keeping these parasites concentrated where they can easily secure access to the host when they become mature. This habit is also important when we attempt to control the fleas and is referred to again under that topic (pp. 25–28).

The number of eggs deposited by a single female and the rate of deposition undoubtedly vary largely with the species, the abundance of food, and climatic conditions. Prof. Bacot, of the Lister Institute, London, in his extensive studies of fleas has conducted a number of experiments bearing on this point. The number of eggs deposited daily is small, but deposition may continue for many weeks. Bacot records 448 eggs as the greatest number observed by him to have been deposited by a single female of the human flea. In some of these experiments he found that the female would continue to deposit eggs for a period of over three months.

THE LARVA.

Within from 2 to 12 days, depending on temperature and moisture conditions, the eggs hatch into minute, whitish, legless, and eyeless maggots. These are not parasitic, but move about actively in the dust and débris in or near the nest of the host. Under favorable conditions the growth of the larvæ is rather rapid. Flea larvæ usually molt twice. The larvæ of the dog flea may molt three times, according to observations made by Mr. Theodore Pergande, of the Bureau of Entomology. The first molt takes place in from 2 to 7 days after hatching, the second from 2 to 6 days later, and the third about 5 days after the second. The shortest larval period observed in these experiments was 7 days. In England Mr. Bacot found that the larval period in the dog flea ranged from 11 to 142 days; in the human flea, from 9 to 102 days; in the European rat flea, from 15 to 114 days; and in the Indian rat flea, from 12 to 84 days. Food, humidity, and temperature are all important factors in influencing the rapidity of development. The larvæ, or maggots, are slender, and each joint is provided with a number of hairs or bristles which assist it in crawling. The head differs slightly in appearance from the other segments and bears some of the usual head appendages with which most insects are supplied. These include short, stout antennæ, or feelers, and a pair of mandibles fitted for biting. The top of the abdomen is provided with two fleshy fingers which aid the larva in its movements,

and a comb of fine hairs. When full grown the maggots are usually less than one-fifth of an inch in length. The larva of a common species is illustrated in figure 3 (p. 14).

The food of the larvæ appears to vary somewhat with the species, since some seem to thrive on a considerable variety of foods, while others are more restricted in their diet. In nearly all species it seems certain that the partially digested blood voided by the adult flea in feeding constitutes an important part of the diet of larvæ, especially when newly hatched. The remainder of the food consists of particles of organic matter, either of animal or vegetable origin, which are found in the cracks of floors, in the nests of the host, or even mingled with the sand near the habitations of the host.

THE COCOON AND PUPA.

When the larvæ have attained full size they spin cocoons of more or less oval shape (fig. 1, *b;* fig. 4). These vary from almost white to brownish, but owing to the particles of sand and dust usually attached the color is often dark. The insect in this stage thus is rendered inconspicuous. In structure the cocoons range from rather light, flimsy silken coverings to very thick tough or even thick brittle encasements. Within the cocoon the larva molts its skin and enters the pupal, or resting, stage (fig. 1, *c*), which somewhat resembles the adult insect. At first the pupa is very pale in color, but it gradually darkens as the time for the appearance of the adult approaches. The length of time spent in the cocoon varies with climatic conditions. At Washington, D. C., Mr. Pergande found that the dog flea would emerge as an adult within from 7 to 9 days after spinning the cocoon. In his experiments in England Mr. Bacot found the period from spinning of cocoons to the emergence of adults to range as follows: European rat flea, from 8 days to over a year; human flea, from 7 to 239 days; dog flea, from 7 to 354 days; and Indian rat flea, from 7 to 182 days.

In these experiments Mr. Bacot found that the period within the cocoon varied markedly with the temperature. This was particularly true with the Indian rat flea, which had its cocoon stage greatly lengthened when the daily mean temperature fell below 65° F. These long resting periods were generally not produced in the case of the human flea until the mean temperature fell to 50° F., and to 40° or 45° F. with the European rat flea. The work of this investigator suggests that the winter is passed in this stage, and that fleas may thus tide over dry hot periods. It is certain that the cocoon offers much protection from adverse weather conditions. The larva may remain quiescent for long periods within the cocoon before actually pupating, and another resting period may occur within the cocoon after the

insect has become adult. Observations made in India and in our own country in the vicinity of San Francisco show that there is no complete cessation of activities in the winter. This is also true as observed in several species by Mr. A. H. Jennings, of the Bureau of Entomology, while in Panama, and the author has observed considerable numbers of fleas on hosts in the Southern States in midwinter. These included the dog flea and the chicken flea, or "stick-tight," as it is colloquially known.

LIFE CYCLE.

The total period from the deposition of the egg to the emergence of the adult, in tests with the dog flea conducted during the summer time at Washington, ranged from 17 to 35 days. The length of the different stages and total life cycle of some of the common species of fleas may be shown best by presenting a table compiled by Mitzmain from the works of various authors, and amplified to include recently published results.

TABLE I.—*Life cycle of fleas in different countries.*

Country and species of flea.	Length of egg stage.	Length of larval stage.	Length of cocoon stage.	Length of complete cycle.
United States:				
Atlantic coast—	*Days.*	*Days.*	*Days.*	*Weeks.*
Dog flea (*Ct. canis*)	2 to 4	8 to 24	5 to 7	2 to 4
Pacific coast—				
Human flea (*P. irritans*)	7 to 9	28 to 32	30 to 34	9 to 11
European rat flea (*C. fasciatus*)	5 to 6	4 to 7	24 to 26	7 to 8
Indian rat flea (*X. cheopis*)	9 to 13	32 to 34	25 to 30	9 to 11
Ground squirrel flea (*C. acutus*)	7 to 8	26 to 28	24 to 27	8 to 9
Europe:				*Days.*
Human flea	4 to 12	8 to 100	6 to 220	19 to 264
Dog flea	8 to 14	12 to 142	10 to 354	35 to 366
European rat flea	5 to 14	12 to 114	3 to 450	20 to 467
Indian rat flea	10 or less	14 to 84	9 to 191	31 to 256
Bird flea (*C. gallinae*)	7 or less	13 to 50	6 to 70+	26 to 127
India:				
Indian rat flea	2	7	7 to 14	21 to 22
Australia:				*Weeks.*
Human flea	6	12	14	4 to 6

LENGTH OF LIFE OF THE ADULT.

Food is the most important single factor in longevity of the flea. Comparatively cool, humid weather greatly lengthens life. Moderately warm, moist weather is more favorable than cool weather for egg laying, but shortens the total life period. Hot, dry weather soon proves fatal to the adult. In connection with this subject reference is made to the work of Mr. Bacot in England, as he has conducted the most complete set of experiments yet published to determine adult longevity. When the temperature registered from 45 to 50° F. and the air was nearly saturated with moisture, this investigator found that specimens of the human flea lived for 125 days, the European rat

flea 95 days and the dog flea 58 days, the Indian rat flea 38 days, and a species of bird or chicken flea (*Ceratophyllus gallinae*) 127 days. These records were made with individuals which received no food whatever. When kept in a box and fed at frequent intervals, he found the human flea to live for more than 513 days. The European rat flea lived 106 days, the dog flea 234 days, the Indian rat flea fed on man 100 days, and the above-mentioned chicken flea 345 days.

In Texas the author has observed the "sticktight," or chicken flea, to live for several weeks attached to a host, but the greatest possible longevity has not been determined.

In experiments conducted in California Mitzmain had specimens of the European rat flea alive for 160 days when fed frequently, the Indian rat flea for 49 days, and the common ground-squirrel flea (*Ceratophyllus acutus*) more than 64 days.

In India and California the longevity with unfed fleas was found to be much shorter than is indicated by the records made in England. Usually the maximum longevity of unfed rat fleas in these warmer climates is but a few days.

Experiments made by Mr. C. Strickland in England, and some conducted by the author in Texas, indicate that the presence of rubbish, dust, or sand, in which the adults may secrete themselves, is an important factor in increasing longevity of unfed fleas. This is especially true during hot, dry weather.

BREEDING PLACES.

In addition to having suitable hosts upon which the adult fleas may feed and thus produce eggs, it is essential that the eggs, the maggots which hatch from them, and the pupæ which finally again produce adults have favorable conditions for development. In houses these conditions are usually found in the cracks of the floors or under matting or carpets. Rat fleas often breed in numbers in granaries, barns, warehouses, and basements, particularly when these are not in constant use or when gunnysacks and rubbish are allowed to accumulate in such places. The immature stages of "sticktight" fleas breed mainly in buildings, such as chicken houses, barns, and sheds which are inhabited by the principal hosts.

Dirt floors in chicken houses or sheds seem to be more favorable than wooden floors for flea development. The young fleas may be found amongst the partially dried excrement, straw, feathers, and other waste in such situations. Fleas have been found also to reproduce in great numbers under corncribs and buildings where dogs sleep or chickens go during the heat of the day. Here the maggots are intermingled with and feed upon the animal and vegetable matter which has accumulated on the soil.

Occasionally fleas, particularly the human flea and dog flea, may breed out of doors. Mr. D. L. Van Dine has recorded an instance in Hawaii where a lawn was infested with the dog flea, and instances are known in the United States of this flea and the human flea breeding in protected situations, as under shrubbery or in the shade of buildings in sand which contains a considerable amount of animal or vegetable matter.

In nearly all cases the breeding places are very closely associated with the haunts or resting places of the host. Instances where adult fleas get upon man well away from such haunts must usually be considered as being the result of the adult fleas having become detached from a host rather than by the fleas having been reared in such situations.

FACTORS INFLUENCING FLEA ABUNDANCE.

Everyone familiar with the flea knows that there is marked seasonal variation in abundance and often distinct variation from year to year. As has been stated, fleas continue to breed throughout the year in California and in parts of our Southern States. This is even more marked in India, Panama, and other tropical countries. The human flea and dog flea are seldom found to worry man during the winter months. This is explained by a falling off in the rapidity of breeding, the comparative inactivity of the adult fleas, and, as Mr. Mitzmain has shown, the tendency for the human flea to remain largely on the lower animals during winter. Throughout the United States the fleas which attack man are most prevalent during the summer months. In India there is a marked decrease in numbers with the oncoming of the hot, dry season. This was particularly noticeable in the case of the European rat flea, which, according to observations of the Indian Plague Commission, began to disappear early in April, and from May 15 to the beginning of November not a single specimen was seen.

The variation from year to year is no doubt principally due to weather conditions. Dr. Howard states that he believes the years of greatest flea abundance are those in which the summer rainfall is above normal. No doubt humid summers, even though the rainfall were not abundant, would produce the same results. These statements are borne out by the effects of dry conditions on the various stages of fleas as observed by several investigators.

Although fleas of one kind or another are to be found all over the United States, there are certain regions where one or more species are especially abundant. In general, in those portions of the country where mild winters and comparatively humid summer atmospheric conditions are the rule fleas are found most prevalent. The amount of rainfall is also a factor in this regional abundance. While

extreme drought is detrimental to reproduction of fleas, excessive rainfall also has a restraining influence. These conditions influencing flea abundance are dependent to some extent on the character of the soil and the presence of hosts and breeding places. Sandy soil is best fitted for flea breeding, as drainage is facilitated and the surface is not so apt to become dried out as on many other soils. In other words, it provides more uniform moisture conditions. It is also probable that sandy soil is of some benefit to the flea by offering more protection to the adult insect.

The local abundance of fleas is, of course, dependent upon factors mentioned in the preceding paragraphs, but in addition the abundance of hosts, their relationship to one another, and the presence of breeding places are of much importance. The abundance of rats in seaports is often responsible for a large flea population, and the continued destruction of the rodents often correspondingly reduces the number of fleas. As has been explained, fleas often feed on several different animals, and when these animals associate they each contribute to the breeding of fleas. An example of this occurs in the instance of the chicken flea, or "sticktight." This flea feeds in great numbers on dogs and cats, and when these animals sleep in and around chicken yards they and their beds are often the source of great numbers of fleas which attack the poultry. Another instance of the effect of the association of hosts and presence of breeding places for fleas may be given. Often untold numbers of fleas may continually infest houses and annoy the inhabitants as a result of hogs, dogs, or other animals being allowed to go beneath the house to make their beds.

THE JUMPING OF FLEAS AND OTHER MEANS OF SPREAD.

The question of the distance a flea can jump, especially in a vertical direction, is important in considering isolation of man or animals from them. The jumping powers of fleas are exaggerated in the minds of most people. The human flea is probably the strongest jumper. Mitzmain, working in California, found the maximum horizontal distance this species could jump was 13 inches. He found a few specimens could jump to a height of $7\frac{3}{4}$ inches. Five inches has been recorded as the maximum horizontal jump of the Indian rat flea by the Indian Plague Commission, and in experiments conducted by Mitzmain $3\frac{1}{8}$ inches was the greatest height to which this species could jump. In other tests investigators found that the European rat flea and common ground-squirrel flea (*Ceratophyllus acutus*) could jump slightly less than $3\frac{1}{2}$ inches in a vertical direction. Observations of the writer on the sticktight flea indicate that its jumping power is almost nil. The legs of this species are comparatively

small, not being developed for jumping like those of the human flea and other species.

Nearly all fleas have more or less difficulty in crawling on smooth surfaces or on clothing, yet in time they are capable of making considerable progress on clothing, either in a vertical or a horizontal direction.

The movements of the fleas themselves are of little direct importance in spreading the species. Their jumping powers, however, aid them in finding hosts and securing attachment thereto, and upon the hosts, whether normal or temporary, they may be carried considerable distances. The species are further disseminated by the scattering of eggs as an infested host goes from one place to another and by the dislodgment of the females from the host. Since the fleas leave a dead animal, in this way adults are scattered, and in some instances they may be infected with the disease from which the host died. The greatest spread of fleas is no doubt brought about through the transportation of infested animals from one place to another through the agency of man. In this way rat fleas may be carried between ports in all quarters of the globe on rat-infested ships. Chicken fleas and dog and cat fleas may also be shipped long distances on infested hosts. It is also possible to spread fleas in merchandise, either in the adult or immature stages. Consideration of these points is of much importance in preventing the spread of plague from one locality to others.

FLEAS AS CARRIERS OF DISEASE.

BUBONIC PLAGUE.

Although the dread disease of man known as bubonic plague has occurred in the United States, the most important outbreak being in San Francisco during the last few years, fortunately it was restricted closely to the portions of the country where it was introduced.

The earliest records of the disease connect the outbreaks in the human family with death among rats. At the present time the disease is considered to be essentially a disease of rats. Man and other animals become infected through the agency of fleas as a result of these epizootics among rats.

The malady has a history dating far back in Biblical times. Probably the worst outbreak known began in the eleventh century and culminated in the fourteenth. During this period practically the entire Eastern Hemisphere was swept, and the number of deaths due to the "black death," as it was known in parts of Europe, was appalling. Within the last 18 years this malady has caused the death of over 7,000,000 in various parts of the world. During the last decade the disease has broken out in various parts of Africa, Europe, Australia, Japan, South America, West Indies, and in the United States.

As a result of international regulations, including quarantines, and owing to the work of the Public Health Service, the disease has not assumed serious proportions in this country. Although the malady has persisted for some time among rats and ground squirrels in and near San Francisco, very few human cases have developed, and the malady has been entirely stamped out in that vicinity. The occurrence of plague in New Orleans during 1914 caused some excitement, but by prompt action by the State and Federal authorities the outbreak has been limited to that city and the number of human cases has been small. In India, China, and a number of other countries the disease is still present in epidemic form, despite the work of the Indian Plague Commission and other organizations for the furtherance of control work. Marked progress is being made, however, and the ultimate stamping out of the pestilence may be expected.

As has been stated, the flea is the medium by which the disease is spread from rats and ground squirrels to man. These insects also act as carriers from rat to rat. That the flea is responsible for the transmission of plague has been determined within the last two decades as a result of studies conducted by a number of investigators in various parts of the world. The importance of an accurate knowledge of these insects in this connection is apparent to all. It has been determined by the Plague Commission of India and other investigators that several species of fleas may serve as vectors of plague. Those which are commonly found on rats and ground squirrels and which may carry plague under certain conditions include the following species:

The Indian rat flea (*Xenopsylla cheopis* Roth.).

The European rat flea (*Ceratophyllus fasciatus* Bosc.).

The human flea (*Pulex irritans* L.).

The European mouse flea (*Leptopsylla musculi* Dugès).

The dog flea (*Ctenocephalus canis* Curtis).

The squirrel fleas (*Hoplopsyllus anomalus* Baker and *Ceratophyllus acutus* Baker).

The cat flea (*Ctenocephalus felis* Bouché).

The rat fleas *Ceratophyllus anisus* Roth. and *Pygiopsylla ahalae* Roth.

The former of the last two mentioned occurs in the East Indies, where it has been shown to be capable of carrying plague, and the latter takes the place of the European rat flea in China and Japan. All of these species, with the exception of the last two named, are found in the United States.

The very severe outbreak of plague in Manchuria a few years ago is thought by many to have started among trappers of the "tarbagan," or groundhog, as a result of having been bitten by the flea, *Ceratophyllus silantiewi* Wagner, which is abundant on this animal.

The Indian rat flea has been found to be by far the most important in plague transmission in India, and this species is now widely distributed throughout the Tropics and in seaports which have direct trade with the Orient. At the present time this species is abundant in parts of the seaport cities on the Pacific and Gulf coasts of the United States. Away from the water front its place as a rat parasite is largely taken by the European rat flea (*C. fasciatus* Bosc.) and the mouse flea (*Leptopsylla musculi* Dugès). The

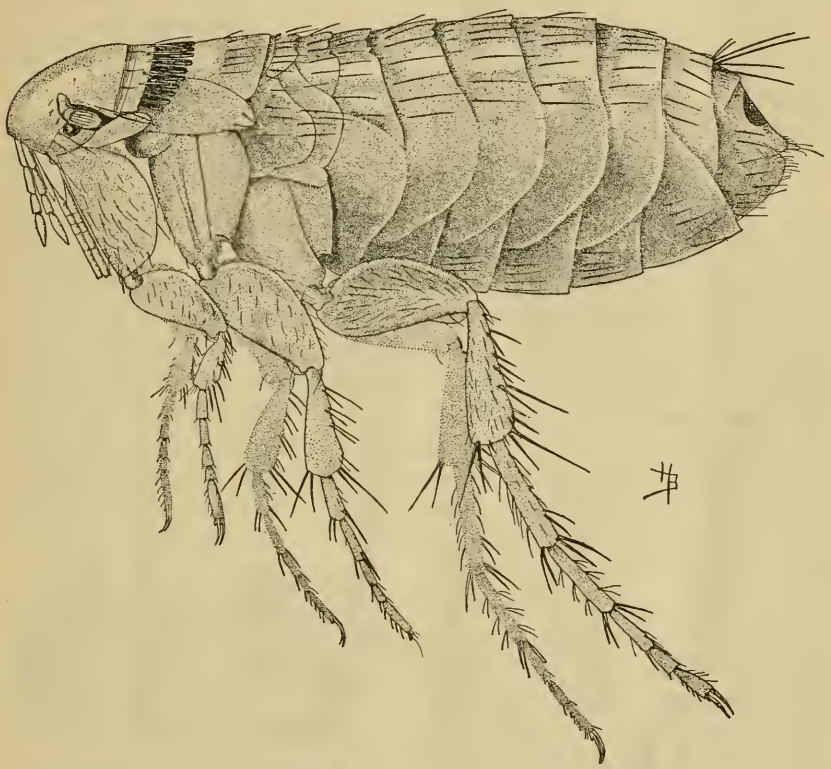

FIG. 2.—The European rat flea (*Ceratophyllus fasciatus*) : Adult female. Greatly enlarged. (Original.)

human flea is common in many parts of the country, and the squirrel fleas mentioned are abundant on ground squirrels (*Citellus beecheyi*) in the western part of the United States. All of these fleas have been found to bite man and will feed on rats. The adult European rat flea is illustrated in figure 2, the larva of this species in figure 3, and the cocoon in figure 4.

As has been stated, plague always occurs among the rodent population before any number of cases develop in man. The rats in a plague-free community usually receive their initial infection from a diseased rat which has been imported from some plague center. This,

together with the favorable conditions as regards rats and fleas in seaports, accounts for the fact that the disease usually first breaks out in such places. The pestilence, when once introduced, is carried rapidly from rat to rat by the fleas. This spread is increased by the fact that most of the fleas leave the rats as they die and pass to others. It is these fleas, set free by the death of their plague-stricken hosts, which form the chief menace to man.

The method by which fleas convey plague germs has received considerable attention, and various theories have been advanced from time to time in an effort to explain the mechanism of transmission. It appears that the two most important methods are by contamination of the skin of man or other host by excrement voided by the infected fleas while feeding and the subsequent rubbing or scratching in of the germ-laden material and by the injection of the disease organism into the wound made by the flea at the time of feeding. Researches made by Mr. A. W. Bacot, of the Lister Institute, have proven this last method to be an important one. He showed that the entrance to the stomach of some of the fleas becomes plugged by a growth of the plague germs. This ultimately prevents the passage of food backward into the stomach, but does not prevent the flea from sucking up small quantities of blood, some of which is forced back into the wound after becoming laden with the disease organism.

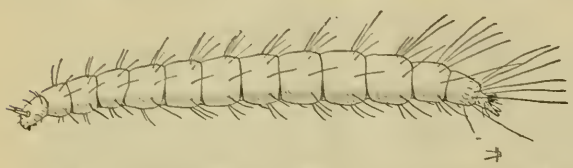

FIG. 3.—The European rat flea: Larva. Greatly enlarged. (Original.)

FIG. 4.—The European rat flea: Cocoon. Greatly enlarged. Note the particles of sawdust and dirt adhering to the surface. (Original.)

Close trade communication between the nations of the world gives increased channels for the dissemination of various pests and diseases as well as opportunities for the furtherance of knowledge and the exchange of trade commodities. The colonization of new lands in the Tropics, the opening of a great artery of trade intimately connecting many of our ports with the commerce of the world, the immigration brought about by the present European strife—these, when considered together with the fact that plague is now present in many quarters of the globe, should impress all with the importance of exercising great care to exclude the disease from our shores. Knowing that this pestilence spreads among people only as a result

of the dissemination of the disease among rodents by fleas, the importance of rodent destruction and of flea control, which go hand in hand, needs no further emphasis. It is not sufficient for the farmer, merchant, and others concerned to depend upon the quarantine authorities to keep plague from being introduced. They must aid the quarantine officers by waging war on the rats and ground squirrels and by preventing flea breeding.

Turning from the rat as a sanitary menace, ample argument is found for its destruction on account of its importance as a destroyer of various agricultural and food products. It has been conservatively estimated that there are in the United States at least as many rats as people. It has also been computed that the annual upkeep of each animal amounts to between $1 and $2. From these figures it is seen that the annual loss due to these rodents must be upward of $100,000,000.

The control of rats is difficult but not impossible, the principal methods being trapping, poisoning, destruction by natural enemies, and, probably most important of all, rat-proofing. The question of the relation of rats to man has been treated in publications of the Public Health Service and of the Bureau of Biological Survey.[1]

This work of rodent destruction, clearing up of breeding places, and rat proofing of buildings has an important beneficial influence on flea conditions. Some of the hosts of the fleas are removed and the breeding places of the insect destroyed to some extent. However, these practices can not be depended upon to control all of the species of fleas important as pests.

KALA-AZAR.

One form of another important group of diseases of the Tropics, known as kala-azar, an infectious fever, is considered by some authorities to be carried by the dog flea and human flea. The particular form of the malady in question occurs in the Mediterranean region. On these shores dogs and children are attacked by a similar disease. Investigators have produced strong evidence that the disease is identical in the two hosts and that fleas are responsible for its transference from the one to the other.[2]

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[1] Lantz, D. E. How to destroy rats. U. S. Dept. Agr., Farmers' Bul. 369, 20 p., 5 fig., 1909.

[2] Fleas and dogs.—In Europe with regard to infantile kala-azar, the dog has been found to harbor Leishmania, and a fairly presumptive case has been made out as to the part this animal plays as an intermediary host, the dog flea being the actual transmitter. Donovan believes, however, that the evidence adduced so far is not in all respects convincing. The occurrence of a natural flagellate of the flea has evidently not been taken into sufficient account. (Donovan, Lieut. Col. C. Kala-azar, its distribution and probable modes of infection. *In* Jour. Trop. Med. London, v. 16, no. 16, p. 253–255, 1913.)

LEPROSY AND OTHER DISEASES.

Leprosy is another serious malady with which, according to some investigators, fleas may be connected. This relationship has not been established, but it is well for us to consider all such possibilities. The part fleas play in the life economy of certain tapeworms has been mentioned, as has also their connection with certain rat-infesting organisms. Various other low forms of animal life, many of which are no doubt parasites of the flea itself, have been found in the organs of that insect in different stages of its life.

FLEAS AS PARASITES OF MAN AND ANIMALS.

As has been shown, a considerable number of the common fleas of this country may be concerned in the transmission of certain diseases if these are once introduced. Several species are, however, of much importance to man aside from their possible connection with disease. It is with the fleas which annoy man or attack poultry or dogs that the people in general are most concerned.

The effect of the bites of fleas varies much with the individual attacked and also with the identity of the flea concerned. The direct effect of these bites, aside from disease transmission, has received little attention. Usually in man pronounced red, itching papules, in some cases with whitish centers, occur at the site of the puncture. Some more susceptible individuals show marked irritation, swelling, and even ulceration following attack. The papules may persist for several days, but usually disappear within a few hours. The irritation is probably induced largely by the injection of the salivary secretion into the wound. This injection causes a rush of blood to the spot, which facilitates the feeding of the insect and in turn causes irritation in the host. The question of acquiring immunity to annoyance by fleas is an interesting one. Many cases have been reported wherein individuals have enjoyed marked immunity to the effect of fleabites and comparative freedom from annoyance after being exposed to the fleas of California. The species concerned in these instances was without doubt the human flea. Others report a similar diminution in the annoyance caused by the dog flea. A brief discussion follows of the more important species from the standpoint of annoyance to man and domestic animals.

THE HUMAN FLEA.

The species of flea known scientifically as *Pulex irritans* L. has long been considered the human flea. It is to be found in practically every portion of the earth frequented by man. It is quite distinct from other fleas in structure (figs. 5 and 6), and is largely dependent

upon man as a host, although in Europe it seems to thrive on the badger, while in the United States it is commonly taken on the skunk. It has also been taken on hogs, rats, and various other animals, but these are usually but temporary hosts and insufficient to maintain the species.

On the Pacific coast the species is responsible for practically all annoyance to man due to this group of parasites. It has been found to be the one concerned in nearly all cases of house infestation in that section. In the Southern and Eastern States, as will be pointed

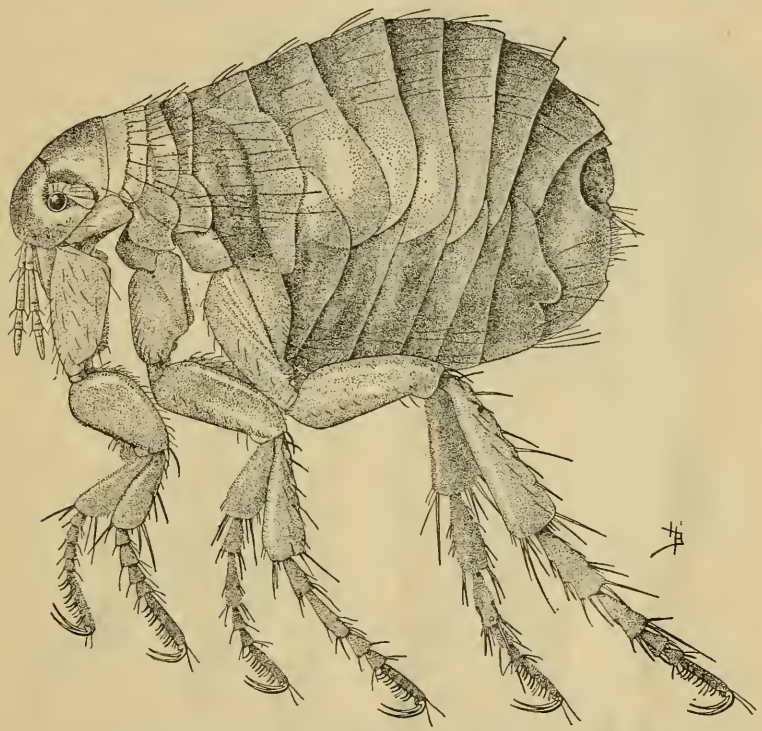

FIG. 5.—The human flea (*Pulex irritans*): Adult female. Greatly enlarged. (Original.)

out later, the dog flea is more important as a pest to man than the human flea. Our main interest in the human flea is on account of its annoyance to man, as it is not as yet known to play any part in disease dissemination in this country. Nevertheless, the possibility of its being an occasional carrier of plague and also that it may transmit the infectious fever kala-azar of the Mediterranean region should not be lost to sight.

Curiously enough, the human flea appears to have adapted itself to the varied conditions under which man lives. It breeds freely in all situations occupied by man, and in the immature stages is one of the most hardy species known to science. The biology of this species,

as compared with others, has been briefly outlined in the preceding pages, and control measures, applicable to this and most other species, are discussed in the following pages.

THE DOG FLEA.

The dog is undoubtedly the normal host for the flea which is known scientifically as *Ctenocephalus canis* Curtis (fig. 1); nevertheless the insect is not averse to partaking of a meal of blood from man or a cat, especially when its normal host is not at hand. Like the

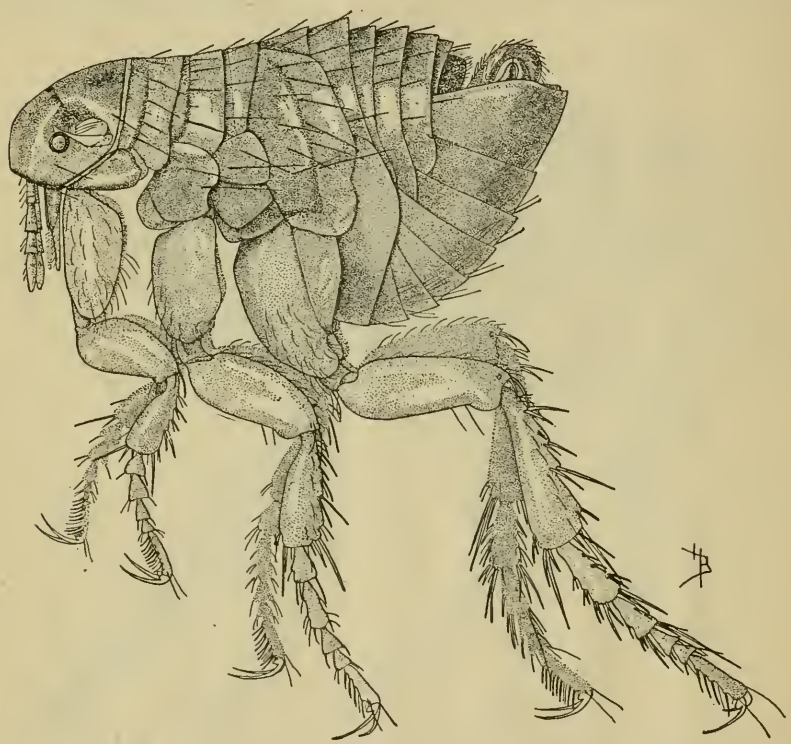

FIG. 6.—The human flea: Adult male. Greatly enlarged. Note the difference in the shape of the abdomen of the male as compared with the female (fig. 5). (Original.)

human flea, this species has a wide distribution throughout the world; in fact, it is generally considered the most widely distributed species of flea.

As an annoyer of man the dog flea ranks next to the human flea. In the eastern United States, as has been pointed out by Dr. Howard, instead of the human flea this is the species usually reported as infesting houses. In some instances reported to the Bureau of Entomology houses have been rendered almost uninhabitable by this aggressive insect. The most severe infestations, as reported by Dr. Howard, have occurred in cases where dwellings have been closed up during summer, and when opened upon returning the occupants were greeted

by hundreds of fleas. Rainy summers are most favorable for such development, supplying enough dampness to the dust, which is left undisturbed in the cracks, successfully to mature the eggs and fleas which are present. The original stock of fleas must, of course, be derived from pet dogs or cats which occupied the house before it was vacated, or, as often happens, dogs may take up their abode under or around the house in the absence of the occupants. Thus great numbers of eggs are dropped, and breeding proceeds undisturbed. It should be noted that the stray dogs and cats which are likely to find homes in unoccupied buildings are often heavily infested with fleas, usually much more so than animals with a home and having more or less attention paid to them.

In this country the dog flea is not known to be responsible for the transmission of any disease, but it holds a position of distinct importance as a household pest. Its importance as an enemy of the dog and cat is not small. Breeders of fine cats and dogs often have considerable trouble in ridding their stock of fleas, and hunting and other dogs, particularly in the South, are kept in poor condition as a result of gross infestation. The fact that one stage of a tapeworm which commonly infests dogs and occasionally children in this country lives within the dog flea still further increases the importance of this parasite.

THE STICKTIGHT FLEA.[1]

One need but visit a few poultry farms or inquire of almost any farmer with his little flock of chickens for home use in the southern and southwestern portions of the United States to get some idea of the importance of the so-called "sticktight flea" (*Echidnophaga gallinacea* Westw.). Other colloquial names which are applied to the insect are "third-party flea," "chicken flea," or "black flea." The name chicken flea is applied because of the frequency with which chickens are infested. Black flea is a name applied less frequently and is given on account of the very dark color of the adult fleas. The name "sticktight" is used most generally in the South, and it is aptly applied. The species differs markedly in feeding habits from most of our common species. It seldom hops about, biting here and there, as in the case of the dog and human fleas, but when a suitable host is found it settles down, deeply inserting the mouth parts, and remains

[1] In a publication just issued (Herrick, Glenn W. Some external parasites of poultry with special reference to Mallophaga, with directions for their control. Cornell Univ. Agr. Expt. Sta. Bul. 359, p. 230–268, fig. 95–116, Apr., 1915.), the point is brought out that the European hen flea, *Ceratophyllus gallinae,* was received from Abington, Mass., and Barker, N. Y. In each of these cases the flea was collected in hen houses, and the collectors state that the insect was very annoying, especially to human beings. Prof. Herrick calls attention to the fact that Mr. C. F. Baker reports the collection of a single specimen of this flea at Ames, Iowa, and refers to a note by Dr. M. Francis to the effect that the species occurred at Bryan, Tex. It is possible that in time this insect may become a pest of some importance to poultry in the United States.

for days or weeks. Its hold on the host is difficult to loosen. Another marked tendency is for the adults to attach to hosts in dense masses. A chicken is frequently seen with a large portion of her head closely set with these fleas, making it appear almost black. These dense masses are often seen on the ears of dogs or cats, particularly at the very edge of the ear. The characteristic appearance of an infested chicken's head is shown in figure 7.

The hosts of this flea are, unfortunately, rather numerous. As has been stated, chickens are commonly attacked, and it is on this host that the species assumes its greatest importance as a pest. In the investigations by the author it has been found in abundance on dogs, cats, tame rabbits, ducks, and turkeys. It is not infrequently found on people who go about infested poultry yards, and children, crawling beneath houses where infested animals go, are often bitten. The species does not attack man very freely. It is seldom found in houses except on rare occasions, when a few specimens may be brought in on the clothing. In one instance in western Texas a burrowing owl was killed and found to be heavily infested about the head with this flea. In another instance in the same region a wood rat, or pear rat, as it is commonly known there, was found to harbor a number of sticktight fleas. Several years ago Prof. J. C. Hartsell, of Orangeburg, S. C., reported to the Bureau of Entomology instances where horses were heavily infested with these fleas on the lower portions of the legs. Others have recorded it from cattle, and a number of specimens have been taken on rats and other hosts in different parts of the world.

FIG. 7.—Head of rooster infested with the sticktight flea (*Echidnophaga gallinacea*). Somewhat reduced. (Original.)

The species was originally described from India, but it now appears to be widely distributed throughout the Tropics and the warm temperate regions. In the United States it is seldom seen north of the Southern and Southwestern States. Reports indicate that the species is spreading; at any rate, it would seem that the South is becoming more generally and completely infested.

No disease has been found to be carried by the sticktight flea, but its importance as a parasite places it among the principal insect enemies of poultry in the South. The principal direct loss is due to the attack of the fleas on young poultry, as high as 85 per cent of young

chickens hatched having been reported lost on account of the fleas. In many cases young chickens, turkeys, and ducks have a combined infestation of sticktight fleas and biting lice, and each contributes to the worriment and weakening of the fowls. A few cases of death observed among grown chickens apparently have been due to fleas. In these instances not only the heads and necks of the chickens were largely covered but numerous patches thickly set with fleas existed under the wings and on the breast. The fowls heavily attacked become droopy, lose appetite, and fall off in weight. Mild infestations on grown fowls cause no marked injury, but no doubt egg laying is influenced to some extent, and certainly infested fowls are unsightly.

The fleas are present on hosts throughout the year, but they are usually more numerous in the summer and fall. The species appears to thrive best in ill-kept chicken houses, where chickens roost under buildings, and where dogs and cats have their beds closely associated with the poultry. This point will be discussed further under the general topic of control. The eggs are dropped by the females while attached to the host. These fall beneath the roost, hatch, and the young larvæ feed on the excrement of the parent fleas and on other animal and vegetable refuse.

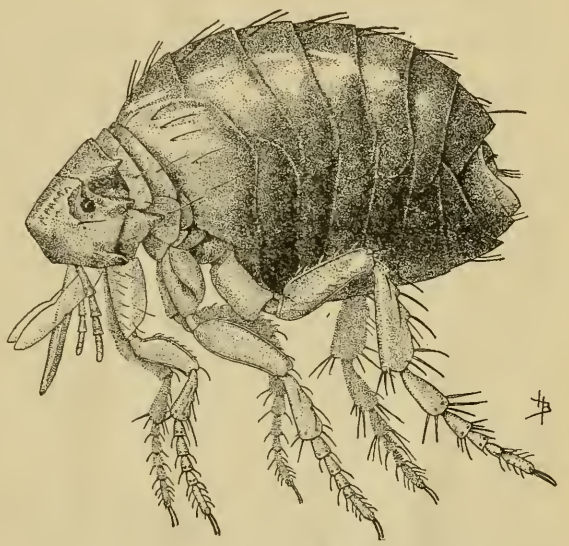

FIG. 8.—The sticktight flea: Adult female. Much enlarged. (Original.)

The species is one of the smallest fleas in this country and very dark brown in color. The body is comparatively short and deep, and the legs are slender, but the mouth parts are large and strong. The male is usually slightly smaller than the female (fig. 8), almost black, and is more frequently seen moving about on the host than the female.

THE CHIGOE FLEA.

The flea commonly known as the chigoe or "jigger" (*Dermatophilus penetrans* L.)[1] is related to the sticktight flea, but has different

[1] This should not be confused with the "chigger" or harvest mite, which is the larval form of Trombidium.

habits. Instead of remaining attached to the surface of the host, the female, after being fertilized, burrows into the flesh until it may become completely embedded. When it first reaches a host it feeds much as does the sticktight flea, the burrowing tendency becoming evident only when the eggs are developing. A number of hosts are attacked, particularly the hog. Cats, dogs, cattle, sheep, horses, and even birds are attacked, but attention has been directed to the species largely through its infestation of man. Its attack is usually confined to the feet of the host, and in man particularly to the toes. The females may enter between the toes or under the toenails, and severe inflammation often follows, with the formation of ulcers, frequently resulting in permanent crippling. While in the host the eggs develop within the female and the abdomen becomes greatly distended, often attaining the size of a small pea. The legs of this species are not large, and when this distention takes place they, as well as the head, become very inconspicuous.

The eggs are deposited while the flea is attached and may drop from the wound or pass out with the detached flea. So far as known the rest of the life history is similar to that of other species.

The chigoe is not known to be established in the United States, although it has been reported on a few occasions from Florida. It is a troublesome pest in the West Indies, in parts of Mexico, and in much of South America. It is native to the American Tropics, but about 1872 it was introduced into western Africa. The African conditions were favorable for the pest, and it soon became established in east Africa and Madagascar and spread to the interior of the continent. It was introduced more recently into India, but it appears to have spread very slowly there.

Conditions in Florida and southern Texas would seem to be favorable for this insect, and if care is not exercised it may be introduced and become established in this country.

NATURAL CONTROL.

As has been stated, hot, dry weather is detrimental to flea development. Likewise excessive moisture in a breeding place destroys the immature stages. The direct rays of the sun in summer are important in reducing the length of life of the adult flea and destroying the immature stages. It is possible to take advantage of these natural factors to a considerable extent in fighting the pest, as is brought out later.

Little is known of the natural enemies of fleas. Certain short-winged beetles termed staphylinids are known to prey upon the adult fleas, and certain species of mites have commonly been found upon them. In Texas ants have been observed to prey upon the eggs and

larvæ. No doubt a number of insect enemies of the immature stages exist, but they are probably less important in control than climatic factors. Chickens seem to be capable under some conditions of interfering with the development of the immature stages of fleas by scratching their breeding place about, and no doubt they eat some of the fleas in their various stages.

ARTIFICIAL CONTROL.

In order to prevent an outbreak of fleas, and more especially to control an infestation which has become established in or about a house, it is usually necessary and always advisable to combine two or more of the measures discussed below in order promptly to control the situation.

DESTRUCTION OF FLEAS ON HOSTS.

In nearly all cases of flea infestation by either the human flea or the dog flea in houses or by the sticktight flea in poultry yards the destruction of the fleas on the hosts is important. Dogs and cats are the animals of particular importance in this connection, since they act as normal hosts for the flea of the dog and cat, which often annoys man; they sometimes harbor the human flea and are frequently heavily infested with the sticktight flea. In cases of house infestation, while it is imperative that the breeding places be treated, attention should be given to dogs and cats. In fact, the destruction of the breeding places and the clearing of the fleas from the hosts should be undertaken simultaneously, as each is essential to the best success of the other. A number of different methods of destroying the insects on animals have been tried, and each has its advocates. The writer has used certain creosote derivations, among them creolin, with excellent results. There are several preparations similar to creolin which would probably be equally effective. It is best to make up a 3 per cent solution of creolin, or one of the similar preparations, in warm water in a tub and place the animal into it; then with a stiff brush to work the solution into the hair. The animal should be kept in the solution 5 or 10 minutes, particular care being taken thoroughly to wet the fleas which crowd to the head of the animal. After the host has been thus treated the creolin water may be drained off and the animal washed with warm water and soap. This washing is not always necessary or advisable in treating dogs, but it is desirable with cats. By this method the burning of the most delicate-skinned animal is avoided. Where a graduated glass measure is not at hand, a 3 per cent solution of the wash may be made by putting in 4 tablespoonfuls of creolin to each gallon of water.

Another treatment, which is reported by Mr. A. A. Girault, of the Bureau of Entomology, to be effective in ridding cats of fleas, is naphthalene. Moth balls were finely pulverized and the powder worked into the fur. The fleas soon began coming out of the hair and on account of their stupefied condition were easily caught and killed. The treatment slightly sickened the cats for two days, but had no serious effect. Insect powder, sometimes called pyrethrum, buhach, or Dalmatian insect powder, may be applied to the fur of animals in the same way. It is not harmful to the host and causes the fleas to come out of the fur in a stupefied condition, when they may be collected on a newspaper and destroyed by burning. It is important that fresh unadulterated pyrethrum be used to secure satisfactory results. The destruction of the chicken flea or sticktight on poultry seems to be rather difficult. Where heavy infestations are present the careful application of kerosene and lard—1 part kerosene to 3 parts of lard—to the masses of fleas gives fairly good results. Care must be taken not to apply too much of the mixture and not to get it on the parts of the fowl where it is not necessary, as it will prove injurious if used too freely.

CONTROL OF HOSTS.

One of the common practices to avoid flea infestation of houses is to keep all dogs and cats out of doors. This is often not desirable, and it also gives an opportunity for the infested animals to start breeding places under the house or in the yard or barn, hence this practice without treating the animals for fleas is objectionable. Not keeping dogs or cats will, of course, largely solve the dog-flea problem, but this is not always feasible. Moreover, the stray animals must also be considered as possibilities in house infestation. From the standpoint of flea control, as well as for the prevention of important diseases, the strict enforcement of dog-control measures and the destruction of all stray cats and dogs is imperative. Dwellings and other buildings should be arranged to prevent cats, dogs, hogs, chickens, and other animals from going beneath them, as the conditions under buildings are often favorable for flea breeding and these locations are exceedingly difficult to keep clean or treat after infestation is started. Numerous instances have come under observation where such conditions were responsible for infested dwellings and heavily infested animals.

Along this same line is the question of separation of hosts. It is bad policy to keep all kinds of animals in close proximity in localities where fleas are numerous. Dogs and cats sleeping around poultry pens are often responsible for keeping chickens constantly stocked with sticktight fleas. Horses kept in buildings where chickens roost

or in barns adjoining chicken coops have been known to become infested with sticktight fleas, and dogs and cats readily infest one another with these and with other fleas. Chickens have been known to become infested with chicken fleas and thus establish an infestation in uninfested yards when allowed to run at large and come in contact with infested premises.

The question of rat control logically should be discussed under this topic, but it has been briefly taken up under "Bubonic plague." Ground-squirrel destruction, aside from its direct economic importance, should also be considered in connection with the relationship between the squirrel fleas, their hosts, and the transmission of plague. The ground squirrels of California are discussed by Dr. C. Hart Merriam in Circular No. 76 of the Bureau of Biological Survey. Much useful information on the control of the California ground squirrel is given, and this is for the most part applicable to ground squirrels in other parts of the country.

DESTRUCTION IN BREEDING PLACES.

Attention has been called (pp. 8–9) to the usual breeding places of different species of fleas. It is evident that destruction of the adult fleas on hosts is almost a hopeless method of controlling the pest if no attention is paid to the breeding places of the immature stages. As has been stated, flea eggs may produce adult fleas from two weeks to many months later. Thus the hosts will continue to become reinfested as fast as the insects upon them are destroyed.

The first step in making war on the breeding places is to determine where the fleas are coming from. Enough has been said in the discussion of life history and breeding habits of fleas to point out the places to be considered. In other than house infestations all unnecessary rubbish and dry animal or vegetable matter should be piled up and burned. In the case of infested chicken houses or sheds the manure should be hauled into an open field and scattered thinly over the ground. When thus exposed all stages are soon destroyed.

Following this preliminary work, which is essential to the success of the subsequent treatment, the ground, outhouse floors, and other places where the breeding is supposed to occur should be sprayed with kerosene, or, better still, crude petroleum should be sprinkled freely about. To prevent reinfestation or breeding it is essential that all waste, both vegetable and animal matter, be kept scrupulously cleaned up. The most inexpensive and satisfactory preventive measure following the destruction of the main infestation is a liberal use of salt scattered about the breeding places and then thoroughly wet down. In many instances observed in Texas the sticktight flea has been kept out of poultry runs by cleanliness

and semiweekly wettings with water. Along the coast salt water from the Gulf is used extensively for this purpose. The soil must be thoroughly wet, as light sprinklings of the surface will not suffice. The watering is most effective when done in the evening, as drying does not proceed so rapidly then as during the day. Mr. D. L. Van Dine, in treating premises infested with the dog flea in Hawaii, used a dressing for the ground under the houses consisting of 20 pounds of air-slaked lime, 3 pounds of sulphur, and 1 pound of buhach. This mixture was applied after the ground had been thoroughly cleared of all refuse. The outbreak was completely controlled in these cases, but it is difficult to say just what part the above dressing played, as the destruction of the adult fleas was undertaken, as well as other measures.

The breeding of the sticktight flea may be prevented to some extent by the use of metal chicken houses, as is advocated for the fowl tick.[1] These galvanized-iron houses provide less protection for fleas than do frame structures, and the intense heat within them during the daytime practically prohibits flea breeding. The dog house should be cleaned out thoroughly at weekly intervals, and if any flea breeding starts the method of destroying the insects, as outlined in the preceding paragraphs, should be followed. By providing a few gunny sacks or a mat for infested animals to sleep upon, it is possible to concentrate the eggs on these. The eggs may be destroyed then by shaking the cloths over a fire or even out on the bare ground in a place exposed to the sun. This should be done about every second day in order to prevent hatching.

Attention is directed to house infestations, which, by the way, are often supplemented by infestations under the houses or in other out-of-door situations. The occurrence of fleas in dwellings is often connected with the keeping of a cat or dog indoors. If this is the apparent source of infestation, the animal should be treated as previously described and kept out until the indoor work is completed.

If the hosts have been confined largely to one room, this is the one to receive most careful attention. The floor covering should be removed, aired, and beaten, the floor thoroughly swept, and all of the dust obtained should be burned, as it contains many immature fleas. It is best, then, to scrub the floor with strong soapsuds or sprinkle it with gasoline, being careful to avoid having fires about. After sprinkling naphthalene crystals or insect powder over the floor, return the floor covering.

Dr. Henry Skinner, of Philadelphia, found that he could control fleas completely in a house by taking one room at a time, scattering

[1] Bishopp, F. C. The fowl tick. U. S. Dept. Agr., Bur. Ent., Cir. 170, 14 p., 5 figs., 1913.

5 pounds of flake naphthalene over the floor, and closing the room tightly for 24 hours. This remedy was found inexpensive, as the naphthalene could be swept up and transferred to another room.

Dr. Howard has called attention to the method of control used by Miss Adele M. Fielde, who has had extended experience with fleas in China. She states that it is possible to control the fleas there by the use of alum. This substance is added to the whitewash or calcimine used on the walls, paper is dipped in a solution of alum and put under rugs and matting, and powdered alum is sprinkled on carpets or other floor covering and swept in. It does not injure the rugs or matting, but banishes the insects, according to Miss Fielde's statements.

In houses where vacuum cleaners are used at frequent intervals the number of fleas coming from the floors may be reduced. In cases of infested houses a thorough cleaning of the carpets and floors with a vacuum cleaner, provided it is efficient, would largely mitigate the pests.

Fleas in different stages in dwellings or other buildings may be destroyed by fumigation with sulphur fumes or hydrocyanic-acid gas. Either of these fumigants, when properly handled, will destroy the fleas, and has the advantage of killing the rats and mice as well. The use of sulphur[1] is efficient and simple, but has the objection of corroding metal and injuring plants. In fumigating, the infested building should be closed up tightly and the sulphur weighed out at the rate of 4 pounds to each 1,000 cubic feet of space. The sulphur is piled up cone shaped in a pan or kettle, which is placed in a larger pan or tub of water to avoid fire from the heat generated. A depression should be made in the top of the cone of sulphur, a little alcohol poured into it, and a match applied. Each room to be fumigated should have a vessel, and large rooms should have two, one located near each end. It is preferable to do all of the fumigation simultaneously. The rooms or building should be kept closed for from 10 to 12 hours. Although this gas is not nearly so dangerous to man as is hydrocyanic-acid gas, the rooms should be thoroughly aired before entering them. The corrosive action of the gas on metals and its effect on plants should not be overlooked. This may be minimized by fumigating when the atmosphere is dry.

Owing to the poisonous character of the ingredients used and the deadliness of the gas generated, fumigation with hydrocyanic-acid gas should not be undertaken without carefully reading the directions[2] for the operation, and then only by an experienced person.

[1] Marlatt, C. L. Sulphur dioxide as an insecticide. *In* U. S. Dept. Agr., Bur. Ent., Bul. 60, p. 139–146, 1906.

[2] Howard, L. O., and Popenoe, C. H. Hydrocyanic-acid gas against household insects. U. S. Dept. Agr., Bur. Ent., Cir. 163, 8 p., 1912.

Sodium fluorid is a comparatively new insecticide which will probably be useful against fleas. This substance is not expensive and not dangerous to handle. The crystalline powder is applied by dusting it over the carpets or floors and working it into the cracks. For the adult fleas it may be blown about the floor and corners with a dust gun or insufflator. Although this substance has not been tried in this way, it is possible that it can be advantageously utilized in chicken houses, dog kennels, etc., by blowing it about the floors with a powder gun. The fact that sodium fluorid is an excellent remedy against cockroaches further commends its use about houses infested with fleas.

A number of things should be mentioned which may be utilized to some extent in flea-infested regions to prevent the breeding of fleas in dwellings. As far as possible, rugs, or art squares, or other coverings which can be taken up and permit keeping the floors more cleanly, and in case of infestation make treatment easier, should be used. Closely matched floors are beneficial, as there are fewer cracks in which the young fleas may develop. Where cracks are present they may be filled with plaster of Paris or putty. The use of floor oil or of efficient sweeping compounds on floors seems to aid in preventing flea breeding.

TRAPPING FLEAS.

Little dependence for control of fleas can be placed on methods designed actually to capture, repel, or exclude from the host the adult fleas if not supplemented by the other repressive measures just discussed. Nevertheless, under certain conditions, such as in instances where a few adults are produced in a great number of situations, thus making complete stopping of breeding very difficult, or while the other methods of control are being put into effect, trapping, repelling, and isolating are of some value. In localities where plague is prevalent, or even suspected, the importance of keeping even a single flea from biting man is apparent.

Where only a few fleas are present in a dwelling and breeding in the floors is not suspected, the adults may be caught by placing a number of sheets of sticky paper on the floor. In extreme cases, where the persons attempting to rid premises of fleas are liable to injury or serious disease, the practice of wrapping fly paper, sticky side out, around one's legs and walking about is sometimes resorted to. The movement causes the fleas to jump, and if they strike the paper they are held fast. The use of sticky fly paper in this way was probably first tried by Prof. S. H. Gage at Cornell University. One of the university buildings was cleared of fleas by having the janitor, with legs wrapped in fly paper, walk back and forth in the infested rooms. Mr. D. L. Van Dine also made use of this scheme in Hawaii.

In this instance, however, it was used mainly to protect the workmen who were clearing up flea-infested premises.

Lights have been used as traps for the adults in some instances. The results will no doubt vary with the species of flea concerned. A light trap which was used by Mr. E. M. Ehrhorn, formerly of San Francisco, is described by Dr. Howard, as follows:

> Fill a glass three-fourths with water, on top of which pour about an inch of olive oil, then place a night float (a little wick inserted in a cardboard disk or in a cork disk) in the center of the oil. Place the tumbler in the center of a soup plate filled with strong soapsuds. The wick should be lighted at night on retiring, or may be used in any dark room. As the soup-plate soapsuds trap is placed on the floor of the room, it does not interfere with the sleeper, and the fleas which are on the floor are attracted to the light.

A small flea trap which is extensively used in parts of China, and is said to be very beneficial, has recently been described by Dr. E. Hindle. In China two pieces of bamboo are used in constructing the trap. A modified form of this trap, which can easily be constructed by anyone, is illustrated in figure 9.

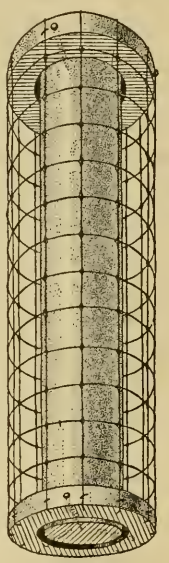

FIG. 9.—Flea trap. The central cylinder is removable and is covered with sticky fly paper. (Original.)

To construct the trap, bore two holes, about an inch and a quarter in diameter, in a board anywhere from one-fourth to 1 inch in thickness. With a keyhole saw or a pocket knife cut out a disk of the board around each of the holes about $2\frac{1}{2}$ inches in diameter. Take a piece of wire netting, with one-fourth or one-half inch square soldered mesh, about 2 feet wide, and tack it around the disks, having one at either end. Cut off the wire, leaving the ends long enough to overlap along the side of the cylinder, and bend the ends in to complete the cylinder. Around a broom handle or other stick about an inch in diameter and equal to the length of the cylinder wrap a piece of sticky fly paper, sticky side out; tack it at each end to the stick and insert the stick into the cylinder. The stick should be fastened in with a nail inserted into it through a hole in the edge of one of the wooden ends. The outer wire cylinder forms a protection for the sticky surface and enables one to move the flea stick around between the bed sheets or to roll it over the flea-infested floor, thus disturbing the fleas, which are caught on the sticky paper. The stick may be easily removed and a new piece of fly paper put on when necessary.

Animals have been used as traps for fleas in experiments conducted by the Indian Plague Commission and others. The Commission

found that guinea pigs left free in rooms picked up considerable numbers of fleas of different species. Men also acted as traps by going about in an infested room, and the fleas thus picked up were caught. No doubt rabbits, cats, or dogs could be utilized in the same way and the fleas destroyed by the methods mentioned under "Destruction of fleas on hosts." This method of picking up fleas is sometimes applicable to certain places in districts where plague exists and it is desirable to capture and destroy the few fleas which might otherwise get upon man.

The use of fresh meat to attract fleas onto fly paper and into traps has been considered to have some merit, but tests made by Drs. Howard and Mitzmain and by others show that it is without value.

REPELLING FLEAS.

The usefulness of repellents is even more limited than that of traps. Many things have been advocated from time to time, or in different sections of the country, for the driving away of fleas. Oil of pennyroyal is probably most widely used for this purpose, and it seems to have considerable virtue as a repellent. This substance may be applied to the shoe tops, hose, and trousers, or placed elsewhere on the body or clothing, and its use on bedding and floors has been advocated by those in flea-infested regions. The pennyroyal plant is used for the same purpose where it grows. Buhach, oil of cedar, eucalyptus oil, or camphor sprinkled between the sheets give a degree of protection to those compelled to sleep in flea-infested places.

ISOLATION FROM FLEAS.

Frequently in many parts of the country outbreaks of fleas are experienced. In such cases extreme measures are necessary for any degree of comfort. Knowing that fleas have very limited powers of jumping in a vertical direction and of crawling on smooth surfaces, it is practicable to exclude them from beds. The higher the bed is from the floor the better, but one may isolate the bed from fleas in most standard-height beds if care be taken to keep the clothing from hanging down. Of course it is essential that no fleas be taken into the bed on the body or the night clothing and that the bedding does not touch the walls or baseboard. It is possible also to isolate a bed or cot or a person sleeping on the floor, if the floor itself is not infested, by placing a band of sticky fly paper or paper covered with a sticky substance 14 inches wide around the bed. In case the legs of a bed are rough, which permit fleas to crawl up them, a band of sticky substance may be painted around the bottoms from 4 to 5 inches above the floor, or, if more convenient, the legs of the bed may be placed in large pans of water.

When the fleas are carriers of disease they are, of course, much more dreaded than when their greatest injury is their bite. Where extreme measures are needed the possibility of a man's protecting himself from fleas while working in infested locations or even while sitting in an infested room by wrapping his legs with fly paper should be borne in mind. A man may get considerable protection from the sticktight flea by wearing khaki or denim trousers and having them tucked into hightop shoes. Leather boots with the tops on the outside of the trousers also keep many fleas from gaining access to the body.

REMEDIES FOR BITES.

As has been stated, fleas in the act of biting inject saliva into the wound, thus producing more or less irritation and itching. Ordinarily no treatment of the bites is necessary; but where they are numerous, especially in the case of susceptible persons, cooling lotions will give relief. Menthol and camphor are beneficial, and carbolated vaseline, carbolic acid in water (a 3 per cent solution), and hydrogen peroxid are each said to relieve the itching and inflammation.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 250

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER July 24, 1915.

FOOD PLANTS OF THE GIPSY MOTH IN AMERICA

By

F. H. MOSHER, Entomological Assistant, Gipsy Moth and Brown-Tail Moth Investigations

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SCOPE OF THE INVESTIGATION.

Since the time the gipsy moth (*Porthetria dispar* L.) became abundant enough in Massachusetts to require treatment in order to prevent the defoliation of trees and shrubs the question of its favored food plants has been under consideration.

During the period from 1890 to 1900 an attempt was made by the State of Massachusetts to exterminate this insect, and a study of the different species of plants upon which the caterpillars would feed was made prior to 1896 and published that year by Forbush and Fernald in their report on the gipsy moth. These experiments were carried on with nearly full-grown caterpillars, a small number being confined in a jar with each food plant. If no feeding was noted in three days the experiment was repeated with other caterpillars, and if the same result was secured for this lot the food plant was considered unfavored by the caterpillars. As a result of these experiments 477 species of trees, shrubs, and plants were tested, and 458 of these were

Note.—This bulletin reports a series of investigations conducted in 1912, 1913, and 1914 to determine the favored food plants of the gipsy moth. The subject is of interest to entomologists and to State authorities engaged in the fight against the gipsy moth in the northeastern States.

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eaten to a greater or less extent. On 27 species the larvæ fed very slightly, and on 19 no feeding was noted.

In 1905, when work to control the gipsy moth was resumed, after a lapse of five years, it was found that the infestation had spread over such a wide territory that extermination of the moth was impossible. The following year (1906) an appropriation was made by Congress and control work to prevent the spread of this insect was commenced by the Bureau of Entomology. The infestation was so heavy in eastern Massachusetts that the principal efforts, aside from parasite introduction, was to clear the main highways in order to prevent the distribution of caterpillars through the medium of passing vehicles. As early as 1907 it was noticed by a number of observers that some species of trees were more often defoliated than others. These observations also indicated that pine was one of the species which was not readily attacked. In order to secure more information on this subject a number of experiments were carried on by the writer under the direction of Mr. A. H. Kirkland, who was superintendent of moth work for the State of Massachusetts.

The preliminary work was commenced in the spring of 1907, newly hatched caterpillars of the gipsy moth being placed in jars and furnished with pine foliage. In the feeding experiments it was not possible to induce newly hatched caterpillars to feed and develop on white pine, but when they were furnished with oak foliage no serious difficulty was encountered. Several field experiments were also carried on to determine whether a pine growth could be protected from the gipsy moth by placing bands of tanglefoot on the trees in order to prevent caterpillars from climbing to the foliage. These experiments were repeated the following season, and on account of the success of the field experiment, wherein several acres of pine growth were protected by using tanglefoot bands, it was obvious that more detailed information regarding food plants was necessary to the proper conduct of the work than had been secured from the experiments reported in 1896. Numerous field observations and several experiments of greater scope were then conducted, but in 1911 it seemed desirable to investigate, in a thorough and systematic way, the entire matter of preferred food plants. Accordingly plans were formulated to carry on an elaborate series of laboratory experiments, using first the more common trees occurring in the infested ments at the Gipsy Moth Laboratory of the Bureau of Entomology at Melrose Highlands, Mass., using first the more common trees occurring in the infested region, with the idea of taking up the rarer species, as well as the woodland shrubs and undergrowth, as soon as opportunity permitted. The experiments were arranged so that two lots of

caterpillars were fed upon the foliage of two trees of the same species, and care was taken that the foliage for each lot was always secured from the same tree. The experiments were begun by using 100 caterpillars that had just hatched for each lot, the plan being to carry on the feeding tests during each of the 6 caterpillar stages (Pl. I, fig. 1) in order to determine any variation in feeding habits in the different larval stages. In conducting these experiments special feeding trays were constructed, and the many details in the keeping of notes and records, the collection of foliage, etc., were worked out. To supplement these experiments and to give data which would furnish a check on the results secured, observations were made throughout the infested region during the summer of 1912 on the feeding habits of gipsy-moth larvæ in the field.

In 1912 the infested territory was divided into 5 sections for the purpose of determining the natural increase of the gipsy moth under varying field conditions. This work has been supervised by Mr. C. W. Minott, and the sections have been in charge of Messrs. H. R. Gooch, I. L. Bailey, E. A. Proctor, J. V. Schaffner, jr., and W. A. Shinkwin. As a part of the summer work each of these men, with one assistant, has secured notes and information on the feeding habits of the gipsy-moth larvæ. The food-plant work has now been carried on both in the field and at the laboratory at Melrose Highlands, Mass., for three consecutive years—1912, 1913, and 1914.

During the summer of 1912 and 1913 a small sublaboratory was maintained at Worcester, Mass., through the courtesy of the board of park commissioners of the city of Worcester. The experiments were in charge of Mr. C. W. Collins in 1912 and of Mr. R. Wooldridge in 1913.

The object of the work at this laboratory was to determine whether the same results would be secured from foliage gathered in an area where the gipsy moth had never become abundant and defoliation had not existed, as compared with foliage taken from the somewhat debilitated tree growth in eastern Massachusetts, where many of the trees had been defoliated one or more times. The results secured indicated that no marked difference could be noted from foliage secured from these two regions, hence the sublaboratory was discontinued at the end of the second season.

The experimental work on food plants of the gipsy moth has now reached a stage from which reasonably conclusive results may be secured. The information is of special value since it forms a working basis for reforestation in the infested areas and is of value in suggesting the tree species which will be more immune from gipsy-moth attack.

EQUIPMENT OF THE LABORATORY.

In early spring a part of the experiments were started in the laboratory, but the trays were soon transferred to a large outdoor insectary. It was found necessary to use canvas curtains on the sides of the insectary in order to shade the trays in fair weather and to prevent the entrance of excessive moisture and wind during storms.

The rearing trays used were of two sizes, depending on the age of the caterpillars. For the small larvæ the trays measured 6¼ by 6¾ by 2 inches, and trays 12¼ by 12¼ by 2½ inches (all inside measure) (Pl. I, fig. 2) were used for the larger caterpillars. These trays were of seven-eighths-inch dressed pine, having a narrow band of tanglefoot applied on the inside of the frame near the top. A piece of cotton cloth was pasted to the bottom of the tray, and two clamps were attached to the inside to hold in place a small bottle, three-fourths inch square and 4 inches long, provided with a crooked neck. The bottle was filled with water and a cork was inserted, through which was placed the end of a sprig of foliage, after which the bottle was secured in the tray by the clamp. It having developed that young larvæ exhausted themselves greatly by trying to crawl around on the cloth bottom of the tray, this covering was abandoned after the first summer's experience and a tray made of paraffined paper (Pl. II), of the proper size to fit into the wooden frames, was substituted. To replace the two brass clamps a single elbow screw was used, which held the bottle firmly but allowed it to be quickly removed.

METHODS OF CONDUCTING LABORATORY EXPERIMENTS.

Early in the spring, trees or shrubs to be used for a food supply were selected and properly tagged. Careful notes were kept of the condition of each, as well as the degree of gipsy-moth infestation upon them and upon the surrounding growth at the time the selection was made. As soon as hatching began feeding trays were given the same serial numbers as the trees or shrubs that had been previously tagged, the foliage from the same plant always being used in the same tray. One hundred newly hatched gipsy-moth caterpillars were placed on the foliage in each tray. The food was replenished daily or oftener if necessary, and a careful record of the number of caterpillars that died or molted was maintained. In cases where all the caterpillars died before pupation, new trays were started, using caterpillars one stage younger than those in the tray at the time it was discontinued.

About 60 species of trees and shrubs were tested annually at the Melrose Highlands Laboratory; and as a number of retests and special experiments were conducted each year, 150 trays were in use continu-

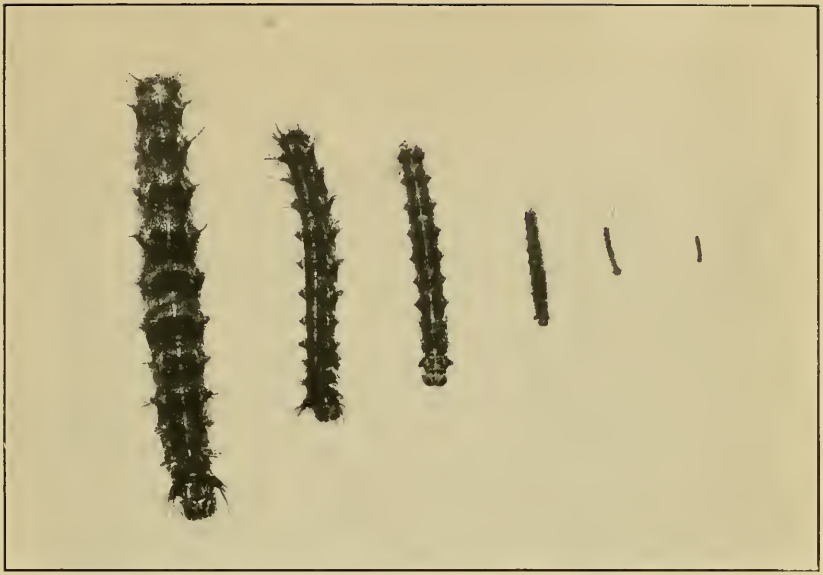


FIG. 1.—GIPSY-MOTH LARVÆ IN FIRST TO FIFTH STAGES. NATURAL SIZE. (ORIGINAL.)

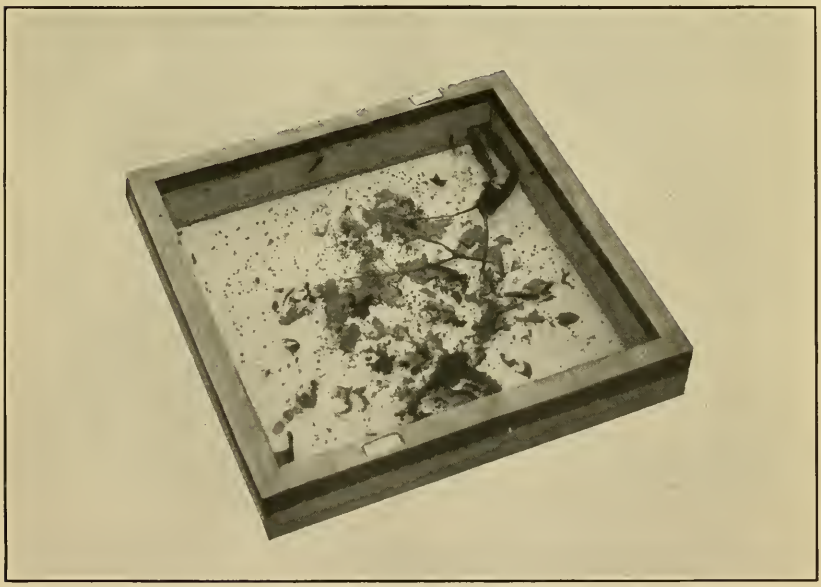
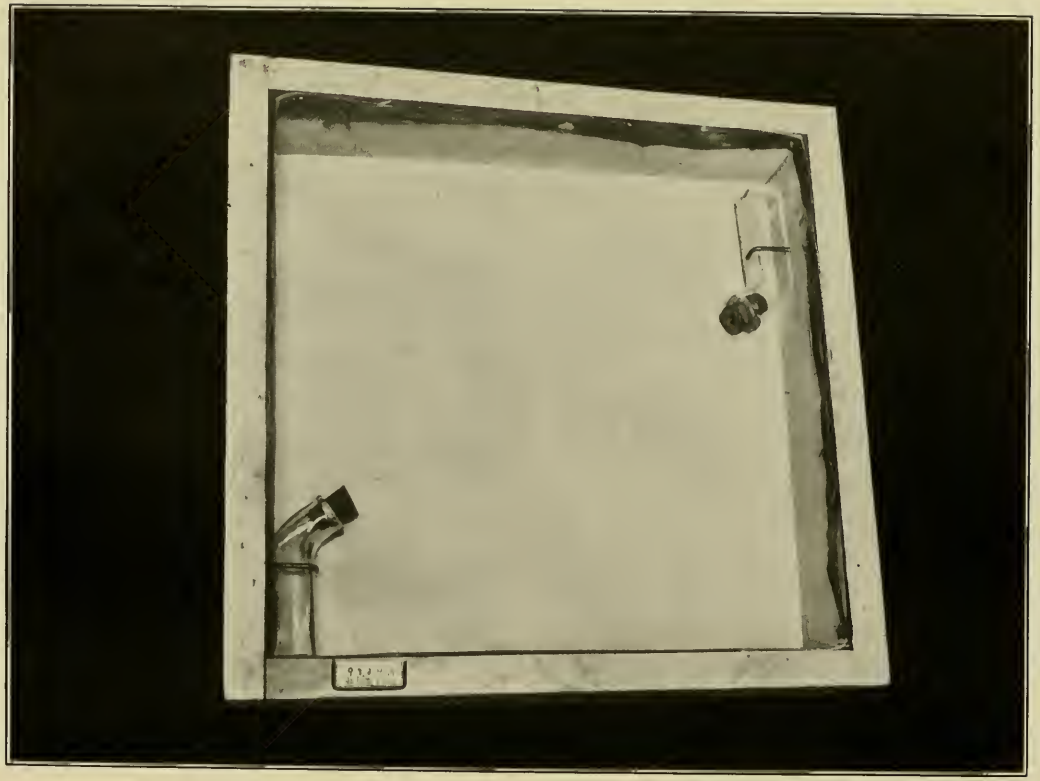


FIG. 2.—TRAY USED FOR FEEDING GIPSY-MOTH CATERPILLARS.

Note that this tray has a cloth bottom, a band of tanglefoot near the top, and is supplied with a bottle of water into which the sprig of foliage is inserted. (Original.)

GIPSY-MOTH LARVÆ AND IMPROVED FEEDING TRAY.



IMPROVED TRAY USED FOR FEEDING GIPSY-MOTH CATERPILLARS.

Note that the bottom and sides are made of one piece of heavy paper which has been treated with paraffin. (Original.)

ously throughout the feeding season. It required the services of five assistants to attend properly to the feeding work and to record the necessary data. In addition, two assistants were employed to collect the food plants that were used in these experiments. Some of the species could not be secured in Melrose, and in a number of cases considerable travel was necessary in order to supply the foliage for the tests. During the summer of 1914 an assistant provided with a motorcycle was able to collect most of the foliage.

About the same number of assistants was required to conduct the experiments at the sublaboratory at Worcester, Mass., during the summers of 1912 and 1913.

A few tests or field observations were made on European trees and shrubs which occur in New England, but no effort has been made in this report to consider the food plants of the gipsy moth in Europe.

DIFFICULTIES IN CONDUCTING THE EXPERIMENTS.

As a result of previous experience in feeding caterpillars, it seemed necessary to secure a better method than simply placing leaves or twigs with foliage in the trays. When this is done the leaves wither rapidly in warm weather and often become so dry that it is extremely difficult to find all the first-stage caterpillars when the trays are cleaned. The use of the bottles of water in the trays obviated this trouble to a great extent and made the cleaning of the trays relatively easy. There were several kinds of foliage, such as linden, sassafras, and young growth of hickory, walnut, etc., that wilted rapidly in spite of every precaution that was taken.

In most of the trays a considerable number of caterpillars died from the disease known as "wilt," and in a few cases the imported parasites produced heavy mortality among the gipsy-moth larvæ. These factors operated in varying degrees during different seasons, but had an important bearing on the number of larvæ that survived the tests.

FOOD PLANTS TESTED.[1]

NOTE.—The writer expresses his appreciation to all who have assisted in these experiments. Special thanks are due to the Board of Park Commissioners of Worcester for the use of the sublaboratory in their city and to Mr. A. V. Parker, superintendent of parks, and Mr. H. L. Neale, city forester, for many courtesies extended; to Dr. C. S. Sargent and his assistants for permission to secure foliage at the Arnold Arboretum for some of the experiments; and to Mr. H. A. Preston for preparing the photographs illustrating this report, as well as to the many other employees of the Gipsy Moth Laboratory who have contributed toward the data summarized in this report.

[1] The botanical designations, both scientific and common names, herein cited are verified by Britton and Brown, Illustrated Flora of the Northern States and Canada. Second Edition, Vols. I–III, New York, 1913.

In the following pages are given a brief statement of the results secured with each food plant tested. Field observations are also included to make the data as reliable as possible. Experience has shown that results, even with the same food plant, vary to some extent during different years; and as the information is based upon three years' work, it is believed that this variability has been given due consideration.

It should be remembered that in the trays the larvæ were furnished with the same species of foliage during the entire season, hence the results are not exactly the same as would be secured under field conditions where a variety of food is usually available. A certain amount of injury to caterpillars always results from handling them in trays, so that the rate of reproduction in the experiments is in all cases less than under field conditions.

Alder, Speckled (*Alnus incana* [L.] Willd.).

In the tray experiments the larvæ fed freely in all stages. The growth and reproduction were normal. The field observers agree that gipsy-moth larvæ usually feed in all stages on this plant, but in the first three stages it seems to be preferred. As alder is of little commercial value it should be removed when cuttings are being made. (Pl. III, fig. 2.)

Apple (*Pyrus malus* L.).

This species was found to be a favorite food of gipsy-moth larvæ both in the field and in the trays. In combination with other growth it is usually the most heavily infested.

Old trees of this species that have been neglected nearly always contain holes and crevices in which the gipsy-moth larvæ hide and go through their transformations, the females depositing their eggs where it is difficult to find them. These trees are a menace to the surrounding growth and should be removed.

Arbor Vitæ (*Thuja occidentalis* L.).

No observations were made on this species in the field, but it has been thoroughly tested in the laboratory. No reproduction was secured until experiments were carried on with third-stage larvæ. The feeding was slight and development was slow and imperfect. It is an unfavored food.

This species can be left in a stand of trees without fear of injury by the gipsy moth.

Black Ash (*Fraxinus nigra* [Marsh.]).

One adult male was reared from 100 larvæ started in the third stage. Many other tests were less favorable to the insect. Mr. T. J. Kennedy, one of the field observers, reports no feeding on this species of ash in southern New Hampshire. It is an unfavored species.

Blue Ash (*Fraxinus quadrangulata* Michx.).

A single specimen of this tree was under observation. It was located in Elm Park, Worcester, and foliage was tested in the trays in the Worcester laboratory by Mr. Collins in 1912.

Although larvæ from the first to the fifth stages, inclusive, were tried, none reached the adult stage. It is an unfavored species.

Mountain Ash (*Pyrus americana* [Marsh.] D.C.).

No observations were made on this species by the field men.

Tray experiments for a single season at Worcester were not conclusive, but the results at Melrose Highlands indicated that larvæ will feed continuously on this plant from the first stage and reproduce normally.

Red Ash (*Fraxinus pennsylvanica* Marsh.).

But few field observations were obtained on this species, and those were to the effect that gipsy-moth larvæ do not feed on red ash.

All larval stages from the first to the fourth, inclusive, were tested at the Melrose Highlands laboratory, but no pupæ were obtained.

When the blossoms were placed with the foliage in the trays, there was considerable feeding on the former but the leaves were not injured.

White Ash (*Fraxinus americana* L.).

This most common species of Fraxinus has been noted by all the field observers, but none reported feeding on the foliage by gipsy-moth larvæ except where other species of trees are nearly or wholly defoliated. Even then there was little feeding in most cases. Mr. Proctor reports that branches on several trees of this species were completely stripped in an area badly defoliated by the gipsy moth.

White ash was tested in 1912 both at Worcester and Melrose Highlands. At the former laboratory, the larvæ from the first to the fifth stages, inclusive, produced no pupæ. At Melrose Highlands trays started with fourth-stage larvæ produced male moths only.

Flame Azalea (*Azalea lutea* L.) and White Azalea (*Azalea viscosa* L.).

Mr. Schaffner had the former species under observation and found that wherever it was situated in badly infested localities feeding on the foliage was rather heavy. This foliage will probably sustain the gipsy-moth larvæ in all stages, but the tray work at Melrose Highlands failed to bring them through from either the first or second stages. From two trays started with third-stage larvæ, male moths were secured.

There was practically no difference in the amount of feeding on these two species.

European Barberry (*Berberis vulgaris* L.).

Barberry has been under observation in the field, and all the observers have found gipsy-moth larvæ in all stages feeding upon it. It is not considered a particularly favored food, as larvæ feeding upon it seemed quite susceptible to disease.

The species will support the larvæ in all stages, adults having been reared from trays started with first-stage caterpillars.

Bayberry (*Myrica carolinensis* Mill.).

In sparsely infested territory, feeding on this species is light, but when the infestation is heavy these shrubs are sometimes completely defoliated.

Reproduction has been satisfactory when small caterpillars have been tested in the trays.

American Beech (*Fagus grandifolia* Ehrh.).

Field observers all agree that gipsy-moth larvæ feed heavily on this species during the first three stages, after which they migrate to other species and usually return to do considerable feeding during the last, or, in some cases, a part of the last two stages. Tray experiments verified this, for in the first three stages there was heavy feeding on the foliage, whereas in the fourth stage there was much less feeding and larval growth was retarded. These caterpillars were restless and appeared to be searching for different food. They died before reaching full growth.

It is evident that the beech must be associated in a mixture with one or more favored species in order that the gipsy moth may reproduce normally.

Black Birch (*Betula lenta* L.).

Field observations indicate that feeding on the black birch is somewhat variable, and it is seldom severely defoliated except in grossly infested areas.

The results secured from the tray experiments were also variable, and while it is possible for larvæ in all stages to survive on this foliage, they usually do not grow as rapidly or develop as vigorous individuals as when supplied with more favored food.

Apparently this tree comes near the line of favored and unfavored species.

Gray Birch (*Betula populifolia* Marsh.).

This species is more generally distributed than any other in the area infested by the gipsy moth.

All the observers agree that the larvæ feed on this birch through all stages and grow large and rapidly except, possibly, in the first stage. Reproduction of the moth on this tree is usually heavy.

In the laboratories the larvæ grew rapidly after the first stage and produced many moths.

One peculiarity was observed in the feeding of the larvæ; both at Worcester and Melrose Highlands the young larvæ fed almost wholly on the petioles of the leaves, severing them from the blades.

Several cases have been observed in the field where the bark on the tender twigs has been completely girdled by the larger larvæ.

This is one of the most favored food plants of the gipsy moth.

Paper Birch (*Betula papyrifera* Marsh.).

This birch is found quite plentifully in the higher altitudes of the gipsy-moth infestation, but in the low altitudes the species is represented by only a few widely scattered specimens.

In the field the larvæ feed on this tree in all stages, and total defoliation results if the infestation is sufficiently great. (Pl. III, fig. 1.)

In the tray work this species proved a very favored food. From one tray of first-stage larvæ at the Worcester laboratory, Mr. Wooldridge obtained 25 egg masses. Heavy reproduction was also obtained at the Melrose laboratory.

Red Birch (*Betula nigra* L.).

This species occurs in a few localities in New England. Mr. Proctor, who had trees under observation in the Merrimac Valley, reports feeding in all stages and defoliation toward the end of the season.

FIG. 1.—PAPER BIRCH FOLIAGE SHOWING PINHOLE FEEDING. (ORIGINAL.)

FIG. 2.—SPRECKLED ALDER FOLIAGE SHOWING SHOT-HOLE FEEDING. (ORIGINAL.)

TWO FOOD PLANTS OF THE GIPSY-MOTH LARVÆ.

WORK OF GIPSY-MOTH LARVÆ IN CRANBERRY.

a, Old growth at base, spring growth, buds, and blossoms near tip; *b*, vines showing where new growth has been cut off by gipsy-moth larvæ; *c*, new growth that has been cut off by gipsy-moth larvæ. Note that little feeding has taken place on the old growth. (Original.)

The tray experiments were not satisfactory because of the difficulty of securing a satisfactory food supply, but all the larvæ grew well in the early stages. Red birch is a favored food plant.

Yellow Birch (*Betula lutea* Michx. f.).

Except in heavy infestations, most of the feeding on this species by gipsy-moth larvæ is done in the first three stages. The larvæ make small holes, extending entirely through the leaves, forming "pinholes," and a few days later "shot holes." If the infestation is bad and the associated species of food plants are defoliated, these birches are sometimes stripped.

In tray experiments male moths have been secured by feeding larvæ started in the first stage.

High Blackberry (*Rubus* sp.).

Field observations indicate considerable variation in feeding on this plant. Defoliation has seldom been reported, and then only when heavy infestations occurred. Under ordinary conditions the feeding on this species is very slight.

Low Blueberry (*Vaccinium vacillans* Kalm.).

Of the three species of Vaccinium under observation in this series of experiments, this is the most unfavorable. Larvæ in the field have been found feeding in all stages, but not to any extent, except in medium to grossly infested territory. Usually the last three stages do most of the feeding on these shrubs.

First-stage caterpillars fed in trays have produced moths, which indicated that the insect can survive on this species.

Tall Blueberry (*Vaccinium corymbosum* L.).

All the field observers consider *V. corymbosum* more susceptible to gipsy-moth attack than *V. vacillans*, but it is not favored when other food is available. When an infestation is fairly heavy it is not uncommon for these shrubs to be entirely denuded.

First-stage caterpillars have developed to the adult stage when fed in trays. The larvæ did not grow as rapidly as is normal and were undersize.

Blueberry (*Vaccinium angustifolium* Ait.).

The field observers pronounce this species the most susceptible to moth attack of our three common species. They note feeding in the early as well as the late stages, and the shrubs may be found in all stages of defoliation. When a tree has been completely defoliated by the larvæ and they migrate to another tree, these shrubs furnish food for the journey.

First-stage larvæ fed in trays grew rapidly and large vigorous adults resulted.

Box Elder (*Acer negundo* L.).

No field observations are recorded on this species.

Tray experiments indicate that this is one of the most susceptible of the maples to moth attack. The larvæ fed freely in all stages and grew to large size; specimens started in the first stage produced moths.

GREENBRIER (*Smilax rotundifolia* L.).

No experiments were conducted on this species at the laboratory.

Observations in the field indicate that this species is seldom attacked.

SWEETBRIER (*Rosa rubiginosa* L.).

Mr. Schaffner found larvæ in the first four stages feeding to a slight extent on this foliage.

No tray experiments were conducted. It is an unfavored plant.

BUTTERNUT (*Juglans cinerea* L.).

In a single instance stripping of this species has been recorded. Mr. Proctor observed this at North Andover, Mass. Other reports indicate very light feeding.

In trays at Melrose Highlands and Worcester males were reared from 100 second-stage larvæ. The caterpillars fed very sparingly and grew slowly. This is an unfavored food plant.

HARDY CATALPA (*Catalpa speciosa* Warder).

No observations were made on this species in the field.

In the Melrose Highland laboratory the larvæ started in the first stage all died before molting. Each succeeding stage was tried, and a few lived long enough to molt once before dying. No adults were obtained. A very unfavored species.

RED CEDAR (*Juniperus virginiana* L.).

This tree is seldom eaten to any appreciable extent by gipsy-moth larvæ, and only in the worst infestations do they show the least feeding on the new growth. It is a common occurrence at the end of the larval season to find trees heavily infested, due to the larvæ having sought shelter from the hot July sun.

Trays were started with this cedar at the Melrose Highlands laboratory, using each succeeding stage of the larvæ from the first to the fifth, inclusive. No moths were produced as a result of feeding on this plant.

SOUTHERN WHITE CEDAR (*Chamæcyparis thyoides* [L.] B.S.P.).

Mr. Schaffner reports considerable feeding on these trees each year, and in 1913 it amounted to 75 per cent defoliation.

Tray records indicate that it is an unfavored species, although one male moth was obtained from 100 fourth-stage larvæ. It is probable that solid stands of this species will not be injured.

WINTERGREEN (*Gaultheria procumbens* L.).

Mr. Shinkwin notes feeding on the leaves of this plant by gipsy-moth larvæ, and in rare instances there was considerable eating of the fruit.

No tray experiments have been carried on with this species. It is unfavored food.

CHOKE CHERRY (*Padus nana* (Du Roi) Roemer).

This species is found as an undershrub in many wood lots. Very little feeding has been noted by any of the observers, and that was done almost wholly by the first three stages, the small larvæ making pinholes in the leaves.

In the trays, both at Melrose Highlands and Worcester, adults were reared. The larvæ thrived about the same as on wild red cherry and were of fair size. This species appears to be the most favored of the cherries.

Sweet Cherry (*Prunus avium* L.).

Trays started with newly hatched larvæ, both at the Worcester and Melrose Highlands laboratories, produced moths. The larvæ fed very slowly, especially in the later stages, and were of small size.

Mr. Shinkwin observed a single roadside tree in a badly infested area that was nearly defoliated by third and fourth stage larvæ.

Wild Black Cherry (*Prunus serotina* Ehrh.).

Adults were obtained from first-stage larvæ started in trays. These larvæ grew very slowly and were only about one-half normal size.

From all sections the observation is made that there is little feeding and by all stages. Mr. Shinkwin notes a case in a heavy infestation where wild black cherry was nearly defoliated.

Wild Red Cherry (*Padus virginiana* (L.) Mill.).

This cherry was fed upon very slightly by the gipsy-moth larvæ, usually in the first two stages and very slightly in the third. The blossoms were attacked more than the leaves.

In the trays at Melrose Highlands adults were secured from first-stage larvæ. They fed sparingly and grew very slowly.

Chestnut (*Castanea dentata* [Marsh.] Borkh.).

This species has been observed by all the field men, and they agree that gipsy-moth larvæ feed upon it to a limited extent in all stages except the first. If favored food plants are abundant, the larvæ soon confine their attention to these plants. Where the infestation is heavy and the favored food is consumed the chestnuts are sometimes stripped.

In the tray work at both laboratories no first-stage larvæ started on this foliage went through to the second stage. Second-stage larvæ fed and adults were secured.

Chokeberry (*Aronia melanocarpa* [Michx.] Britton).

First-stage larvæ fed freely on this species in the trays and produced adults. A small amount of feeding was noted in the field, mainly on the blossoms.

Cornus (*Cornus* sp.).

Mr. Proctor notes pinhole feeding on this species in the field, but the other observers do not record any feeding in the other sections.

In the trays none reached the adult stage, although tried with the different stages of the larvæ. It is an unfavored species.

Flowering Dogwood (*Cynoxylon floridum* [L.] Raf.).

This species was tried in the laboratory at Melrose Highlands with each successive stage of gipsy-moth larvæ and none reached the adult. More feeding was noted on the flowers than on the leaves. In the field, even in badly infested territory, only very slight feeding was noted. It is an unfavored species.

Red Osier (*Cornus stolonifera* Michx.).

In heavily infested territory some of the field observers have found slight feeding during the early part of the year. This did not extend beyond small holes in the leaves and notches in the edges.

In the laboratory each successive larval stage was tried on the foliage and no adults were obtained.

Cottonwood (*Populus deltoides* Marsh.).

Cottonwood is seldom found in this section, but was tried in the trays in order to know whether it is favored in case the moth spread to territory where this species is common.

About 10 per cent of the first-stage larvæ started on this foliage carried through to the second stage, when they all died. At least 10 per cent of the third-stage larvæ started in trays reached the fifth stage, but no adults were obtained. In the early stages the feeding was slight and growth accordingly slow, but in the later stages feeding was more free and growth more rapid.

No observations were made on this species in the field.

American Cranberry (*Oxycoccus macrocarpus* [Ait.] Pursh).

The larvæ eat but little of the foliage of the cranberry vines, but cut off the stems just above the old growth and also the stems of the flowers or newly set berries. (Pl. IV.) The habit of the larvæ is to feed at night and remain secreted during the day. By parting away the vines the larvæ may be found underneath, next to the cool earth, ready to come up when the sun goes down to continue the feeding. Bogs that appear to be entirely free of the pest may harbor great numbers that will greatly reduce the crop.

In the trays we failed to obtain adults from larvæ started in the first stage on this foliage. On the bogs, however, was evidence that larvæ hatched on the vines had come through to the adult stage without other food.

Red Currant (*Ribes vulgare* Lam.).

Tray experiments failed to produce any adults, although the different stages were fed upon the foliage. In the early stages there was more feeding according to size of larvæ than in the later stages, and the larvæ lived longer.

Mr. Schaffner noted very slight feeding on this species in the field. It is an unfavored food plant.

Bald Cypress (*Taxodium distichum* (L.) Rich.).

Bald cypress was tried with all larval stages in the trays and only a very small percentage went through to the next stage. None reached the adult stage. Feeding was very slight and there was practically no growth. It is an unfavored species.

Dangleberry (*Gaylussacia frondosa* (L.) T. & G.).

Larvæ in the third stage started on this foliage reached the sixth stage. No pupæ were obtained from any stage.

Mr. Schaffner made observations on this undershrub in the field and in one instance notes a defoliation of 50 per cent, but as a rule there is but slight feeding.

BUSH HONEYSUCKLE (*Diervilla diervilla* [L.] MacM.).

This is a very common shrub along roadsides and in waste places. Mr. H. W. Allen reports that it was not eaten in an infested area at Manchester, N. H. It is an unfavored species.

NARROW DOCK (*Rumex crispus* L.).

Mr. Bailey reports seeing first and second stage larvæ feeding on this dock in Pelham, N. H. But little feeding was noted, however. It is an unfavored species.

AMERICAN ELDER (*Sambucus canadensis* L.).

This foliage was used in trays for all stages of gypsy-moth larvæ up to and including the fourth stage, and but very few changed to the next stage. There was very slight feeding and no growth.

Several observers have seen larvæ on this species, but none note any feeding beyond a few pinholes or notches in edges of the leaves. It is an unfavored species.

AMERICAN ELM (*Ulmus americana* L.).

All stages of the larvæ were noted feeding on elm, but usually to a limited extent. In heavily infested areas, where other species are completely defoliated, the elm shows much feeding, but it does not appear to be a favorite food if other species are available. In the trays, adults were reared from larvæ started in the first stage on elm foliage. The growth, however, was slow and the feeding light.

The preference for this food seems to have changed in the last 20 years. In the early nineties the elms were considered favored food. In the spring and summer of 1894 elm was the food used in nearly all the experiments carried on in the Massachusetts State Laboratory, then located in Malden, Mass. The larvæ fed freely on it and grew rapidly. In the trays in 1912 it was apparently distasteful to them and they were constantly searching for other food.

ENGLISH ELM (*Ulmus campestris* L.).

Our only knowledge on this elm is from the tray experiments. The larvæ fed about the same on this species as on the native elm, but none reached the adult stage. A few reached the fifth stage that were started in the third stage. In the open they could probably develop from the egg to the adult.

SLIPPERY ELM (*Ulmus fulva* Michx.).

Tray experiments show this to be an unfavored food plant. Few larvæ passed to the next higher stage while being fed upon it.

Mr. Proctor notes slight feeding in the field in all stages where the infestation was heavy.

SWEET FERN (*Comptonia peregrina* [L.] Coulter).

Larvæ in all stages have been observed feeding on this shrub and in heavily infested localities defoliation has taken place. In spite of this evidence it is not a favored food, and if other species are present in considerable numbers the feeding is not usually heavy on sweet fern.

Tray experiments show slow feeding and very little growth. But few larvæ passed to the next higher stage.

SPICE-BUSH (*Benzoin aestivale* [L.] Nees).

No field observations have been made on this rather common shrub.

In the trays the larvæ in all stages seemed to dislike the food and there was little or no growth. Death resulted in a short time from starvation and disease.

BALSAM FIR (*Abies balsamea* [L.] Mill.).

Mr. Gooch has had this species under observation. On July 14, 1914, he found in a mixed growth which was nearly defoliated heavy feeding on this species by fifth and sixth stage larvæ. A few small trees were 75 per cent defoliated. No feeding was observed by earlier stages.

In the trays little feeding took place before the third stage, and then the larvæ began to die rapidly and no adults were reared. This is an unfavored species.

SWEET GALE (*Myrica gale* L.).

Foliage from this species used in two trays with newly hatched larvæ produced adult moths. This shows it to be a favored food plant, as the larvæ fed freely in all stages.

Mr. P. S. Coffin found fourth and fifth stage larvæ feeding freely on sweet gale in Candia, N. H. None of the other stages have been observed feeding upon it in the field.

GRAPE (*Vitis labrusca* L.).

Tray experiments with the foliage of wild grape with each stage of the larva shows that the latter will die before reaching the next stage. There was very little feeding, which consisted of small notches being made in the edges of the leaves.

Mr. Schaffner made observations on this plant in the field which agree with the results secured in the laboratory.

HACKBERRY (*Celtis occidentalis* L.).

Newly hatched larvæ started on this foliage reached the fifth stage before the last one died. They did not appear to care for the food and grew very slowly.

Mr. Schaffner watched one tree of this species, but found no feeding at any time upon it.

PINK HARDHACK (*Spiræa tomentosa* L.).

All stages of the larvæ have been observed on this species in the field and slight feeding has been reported, but the foliage will not sustain life through the different transformations.

Larvæ in the trays died before reaching the succeeding stage.

WHITE HARDHACK (*Spiræa salicifolia* L.).

Tray experiments and field observations show that this species is unfavorable, since larvæ are unable to develop sufficiently to transform to the next stage.

HAWTHORN (*Crataegus* sp.).

Field reports indicate that this species is freely eaten by the larvæ in all stages.

This species was tested in the Worcester laboratory and the larvæ fed freely in all stages, grew well and went through from first stage to adult. It is a favored food plant.

Hazelnut (*Corylus americana* Walt.).

This is a favored food plant for all stages of the larvæ, although feeding is heavier during the first four stages.

In the laboratories the feeding in trays was general in all stages and male and female moths were reared from larvæ started in the first stage.

Beaked Hazelnut (*Corylus rostrata* Ait.).

Not as common as the above species. Field observations same as for *C. americana*.

Laboratory experiments had to be discontinued after the larvæ reached the third stage because the shrubs were sprayed with poison.

Hemlock (*Tsuga canadensis* [L.] Carr.)

This evergreen is capable of supporting life in all stages of the gipsy-moth larvæ. At the Worcester laboratory, Mr. Collins reared 2 males and 1 female from the two trays of first-stage caterpillars. At the Melrose Highlands laboratory no adults were reared.

The field observers note feeding in all stages on the foliage, but in the first stage it is the new growth only. The feeding increases in intensity with each successive stage. In the field few adults develop when this tree is the exclusive diet of the gipsy-moth larvæ. (Pl. V.)

Bitternut Hickory (*Hicoria cordiformis* [Wang.] Britton).

No field observations were made on this hickory.

In the trays the larvæ fed quite freely in the first three stages, but the foliage appeared somewhat distasteful to them in all stages.

The tree will doubtless sustain the caterpillars through life, but is not a favored food plant.

Mockernut Hickory (*Hicoria alba* [L.] Britton).

This seems to be the most favored species of the hickories. Mr. Shinkwin reports nearly total defoliation of a few trees. Feeding is most noticeable in the early stages.

In the trays, first-stage larvæ were reared to the fifth stage only.

In heavy infestations, in a mixed growth, this tree may be severely defoliated.

Pignut Hickory (*Hicoria glabra* [Mill.] Britton).

Pignut hickory has been watched by all the observers and slight feeding upon it has been noted in all stages. All are of the opinion that it is an unfavorable food plant. The first-stage larvæ begin feeding upon the bud scales and follow up by eating holes in the new unfolding leaves.

In the trays at Melrose Highlands started with first-stage larvæ, male moths were obtained. At no time was the feeding free, and growth was very slow.

Shagbark Hickory (*Hicoria ovata* [Mill.] Britton).

Shagbark hickory is eaten by the gipsy-moth larvæ less than the other hickories. The field observers report considerable feeding on the bud scales and after these drop the feeding diminishes. All stages have been reported feeding upon it sparingly.

In the trays, both at Worcester and Melrose Highlands, larvæ started in the first stage died on or before reaching the third stage.

American Hornbeam (*Carpinus caroliniana* Walt.).

All larval stages feed upon this foliage, and defoliation results in badly infested territory.

This species was tried in both laboratories, and first-stage larvæ died on or before reaching the third stage.

Hop Hornbeam (*Ostrya virginiana* [Mill.] Willd.).

In the tray experiments at Melrose Highlands and Worcester first-stage larvæ failed to develop beyond the third stage on this foliage.

Larvæ feed on this foliage in all stages in the field.

Highbush Huckleberry (*Gaylussacia baccata* [Wang.] Koch).

This is an unfavored food plant and will not sustain the larvæ until they are full grown. The observers report seeing the larvæ in all stages feeding upon this species; in most cases they were probably larvæ that had spun down from overhanging trees.

In the trays a few male moths were obtained from larvæ started in the second stage.

Inkberry (*Ilex glabra* [L.] A. Gray).

In southeastern Massachusetts this species is common over large areas.

Tray experiments and field observations both show that the larvæ can not subsist upon it.

Smooth Winterberry (*Ilex lævigata* [Pursh] A. Gray).

Larvæ have been reported on this species in all stages eating small holes or notches in the leaves. These were probably larvæ that had been shaken down from overhanging trees or had crawled from near-by species. None seemed to stay for extended feeding.

In the trays there was very slight feeding and no growth. The caterpillars died rapidly of starvation.

American White Holly (*Ilex opaca* Ait.).

Mr. Schaffner reports finding larvæ in the third, fourth, and fifth stages feeding slowly on this species.

Larvæ in the trays fed sparingly in the first stage, but died rapidly of starvation. In the succeeding stages there was hardly any feeding, and death resulted.

Feverbush (*Ilex verticillata* [L.] A. Gray).

Tray experiments and field observations show that gipsy-moth larvæ will not subsist on this species. A few small notches in the leaves observed in the field and notches and small holes in the leaves in the trays constituted all the feeding. Larvæ died rapidly and did not grow at all.

Larger Blue-flag (*Iris versicolor* L.).

Mr. Kennedy found fourth and fifth stage larvæ feeding on this species in Hampton, N. H. The swamp was situated near a group of gray birches that were badly stripped; the larvæ were being blown off by the wind, and in searching for food crawled to these plants and partially defoliated them.

FIG. 1.—NORMAL HEMLOCK FOLIAGE, PHOTOGRAPHED JUNE 20, 1914. (ORIGINAL.)

FIG. 2.—HEMLOCK TWIG PARTLY DEFOLIATED BY FOURTH-STAGE GIPSY-MOTH LARVÆ; PHOTOGRAPHED JUNE 20, 1914.

This tree was stripped of foliage before midsummer. (Original.)

WORK OF GIPSY-MOTH LARVÆ IN HEMLOCK.

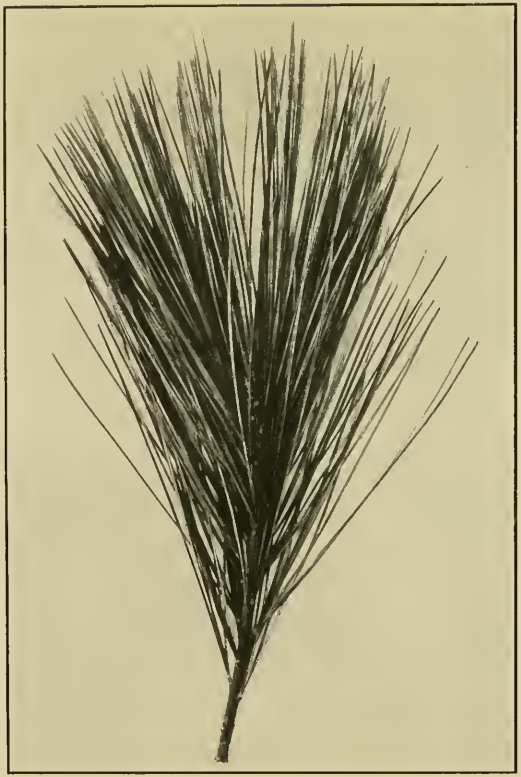


FIG. 1.—NORMAL WHITE-PINE FOLIAGE. (ORIGINAL.)

FIG. 2.—WHITE-PINE FOLIAGE BADLY INJURED BY GIPSY-MOTH LARVÆ.

Note the notches eaten in many of the needles.

WORK OF GIPSY-MOTH LARVÆ IN WHITE PINE.

Poison Ivy (*Toxicodendron radicans* [L.] Kuntze).

Feeding by all stages except the sixth has been noted upon poison ivy. This resulted in a number of notches and small holes being made in the leaves. It is not a favorable food plant.

Juniper, Common (*Juniperus communis* L.).

Many of the field observers have seen feeding by gipsy-moth larvæ on this species in all stages, usually on the new growth.

Laboratory work shows that this species will not maintain this insect through the larval stage.

Kentucky Coffee-tree (*Gymnocladus dioica* [L.] Koch).

This species was tested at Worcester and also at the Melrose Highlands laboratories. In the first stage, before the bud scales dropped, there was considerable feeding. Later there was practically no feeding in any of the stages.

No field observations have been made on this species.

American Larch (*Larix laricina* [Du Roi] Koch).

Tray experiments show this to be a favored food for the gipsy-moth larvæ. They fed freely in all stages and grew rapidly and to large size. They were, however, badly attacked by disease, but adults were secured from experiments begun with first-stage caterpillars.

No field observations were made on this species.

European Larch (*Larix decidua* Mill.).

Mr. Proctor notes feeding by first-stage larvæ on this species and in a diminishing degree in the second and third stages, after which no more feeding was noted. Observations were made in only one locality, and the species was not tested in the trays in the laboratory.

Mountain Laurel (*Kalmia latifolia* L.).

Tray experiments show that this laurel will not support life of the gipsy-moth larvæ, as they would not feed upon it to any extent and die rapidly from starvation.

Two observers have seen slight feeding on this shrub by first, fourth, and fifth stage larvæ, the two latter stages working on the blossoms as well as the leaves.

Sheep Laurel (*Kalmia angustifolia* L.).

Field observations and tray experiments show that this species is distasteful to the caterpillars, as they eat only when no other food is available and then to a very limited extent. In the trays the larvæ died rapidly when furnished with no other food.

Swamp Eubotrys (*Eubotrys racemosa* [L.] Nutt.).

Considerable feeding by all larval stages has been observed by Mr. Schaffner on this species in Middleboro.

In the trays it does not appear a very favorable food and no pupæ were obtained, as all larvæ died of disease and starvation.

American Linden (*Tilia americana* L.).

All field observers agree in calling this a favorable food for the gipsy-moth larvæ. It is eaten freely by all stages and is especially favored during the first three larval stages.

In the trays a fair percentage of adults were obtained from first-stage larvæ.

European Linden (*Tilia* sp.[1] L.).

Mr. Schaffner notes considerable feeding on this species by second and third stage larvæ.

In the trays this species did not seem to be as favored as the preceding one; the larvæ died rapidly and none pupated, although several reached the fifth stage.

Black Locust (*Robinia pseudoacacia* L.).

Slight feeding by all stages of the gipsy-moth larvæ has been observed in the field in mixed growth, where the infestation was bad.

In the trays the larvæ fed very sparingly and died rapidly. None before the third stage were carried to the adult stage, and all those reared were male moths. It is an unfavored species.

Honey Locust (*Gleditsia triacanthos* L.).

Results of the tray work show that this species ranks the same as the preceding.

No observations have been made in the field on honey locust.

Pepper-bush (*Xolisma ligustrina* [L.] Britton).

Slight feeding by gipsy-moth larvæ in all stages has been observed on this species in the field.

In the trays, feeding was very slow and little or no growth resulted. It is an unfavored species.

Mountain Maple (*Acer spicatum* Lam.).

No field observations have been made on this maple.

In the trays the first-stage larvæ fed freely, but after passing into the second stage feeding was much less, and none developed beyond the third stage.

Very little feeding occurred in the later stages and no adults were obtained.

Norway Maple (*Acer platanoides* L.).

Adults, both male and female, were obtained from the trays started with first-stage larvæ on this foliage. The larvæ fed freely, especially in the later stages, and grew to good size.

No field observations were made on this maple.

Norway maple and the box elder are the most favored species of the maples. They are not as freely eaten, however, as many other food plants.

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[1] *T. platyphyllos* and *T. vulgaris* are the lindens usually included by nurserymen as *T. europæa*, hence the designation *Tilia* sp. is adopted in the absence of specific determination.

Red Maple (*Acer rubrum* L.).

When this maple is mixed with other trees more favored by gipsy-moth larvæ and the infestation is light, the feeding in all stages is light. When the infestation is heavy and the other trees in the combination become defoliated, or nearly so, the feeding becomes more intense, and in some cases defoliation of this maple results. It is not, however, a favored food and will usually be deserted for other species.

In the laboratory, adults were obtained from trays started with first-stage larvæ on this foliage.

Silver Maple (*Acer saccharinum* L.).

In trays, first-stage larvæ did not develop and produce adults, as all the former died in the fourth or earlier stages.

No field observations were made on this species. This is not as favored a food as red maple.

Striped Maple (*Acer pennsylvanicum* L.).

Larvæ started on this foliage in any stage failed to reach the next stage. It is one of the most unfavored of the maples.

No feeding of any amount was observed in the field.

Sugar Maple (*Acer saccharum* Marsh.).

Very few observations on this species have been made in the field, but the observers are agreed that it is an unfavored food.

In the trays at Worcester and Melrose Highlands the first-stage larvæ grew fairly well and a few male and female moths were obtained. It is less favored than Norway maple and about as susceptible to attack as the red maple.

Red Mulberry (*Morus rubra* L.).

Mr. Collins tested this species in the laboratory at Worcester and found it an unfavorable food for the gipsy-moth larvæ. A few specimens passed into the following stage, but none lived through two stages of it. No field observations have been made.

White Mulberry (*Morus alba* L.).

White mulberry was tested in the trays at Melrose Highlands and about the same results were obtained as with the red species, except that it is slightly more favorable than the former. One male was reared from a tray started with second-stage larvæ.

No field observations were made on this species.

Black Oak (*Quercus velutina* Lam.).

The oaks are among the most-favored food of the gipsy-moth larvæ. The young larvæ begin feeding as soon as the buds are about half open. This is a favored species and is eaten freely by all stages of the caterpillars and produces large and vigorous adults.

Rock Chestnut Oak (*Quercus prinus* L.).

This species is not common in the infested area, but wherever found the observers were unanimous in their reports that it is very favorable food.

The same conclusions were drawn from the tray experiments. The larvæ fed freely in all stages, growth was rapid, and they attained large size. A good percentage reached the adult stage.

Dwarf Chestnut Oak (*Quercus prinoides* Willd.).

No observations were made on this species in the field.

The larvæ fed freely in the laboratory during the first two stages. It then became necessary to discontinue the experiments, as the specimen trees were sprayed. It is undoubtedly a favored food plant.

Bur Oak (*Quercus macrocarpa* Michx.).

Larvæ fed freely on this foliage in all stages and grew rapidly, but all died of disease by the time they reached the sixth stage.

No field observations were made on this species.

Pin Oak (*Quercus palustris* Du Roi).

Larvæ fed on this foliage freely in all stages in the trays, especially in the first stage, but none reached the adult stage on account of disease.

No field observations were made on this oak.

Post Oak (*Quercus stellata* Wang.).

Trays started with newly hatched larvæ on this foliage produced adult moths. Larvæ fed freely in all stages.

No field observations were made on this species.

Red Oak (*Quercus rubra* L.).

This is one of the most abundant oaks and the records of field observations are voluminous. All are agreed that the larvæ feed ravenously on it in all stages and that large vigorous larvæ are produced. This is usually one of the first species to be entirely defoliated in a mixed growth.

In the trays the larvæ fed freely in all stages and good reproduction resulted.

Scarlet Oak (*Quercus coccinea* Wang.).

In most of the infested territory this oak is found to some extent and all are agreed that it is eaten by larvæ in all stages, but usually not quite as freely as white, red, or black oak.

Tray work shows it to be a favorite food, as a good proportion of larvæ went through to the adult stage.

Bear Oak (*Quercus ilicifolia* Wang.).

As a food for gipsy-moth larvæ this is one of the most favored oaks. Not all the observers had this species in their divisions, but those that did agree as to the favorability.

In the tray work the same thing was shown, as the larvæ fed freely in all stages.

Shingle Oak (*Quercus imbricaria* Michx.).

This oak is a favored food for gipsy-moth larvæ, especially after the first stage. A good proportion of male and female moths were reared.

No field observations were made on this species.

Swamp White Oak (*Quercus bicolor* Willd.).

The feeding in the trays was not quite as free on this species as on some of the oaks, but a fair percentage of adults were reared.

The field observers do not all agree as to the favorability of the species, as some consider it the most favored oak, while others find that it is not preferred as much as other oaks.

White Oak (*Quercus alba* L.).

This species does not put out foliage until after the other oaks and other trees in the combinations have come into leaf. The larvæ feed on the swelling buds, and many desert this species for the red, black, and scarlet oaks. This accounts for the early stripping of the other species.

Tray work and field observations show that the white oak is probably the most favored food plant of the gipsy moth.

Osage Orange (*Toxylon pomiferum* [Raf.]).

Tray experiments with this species show it is not a favored food. No pupæ were obtained and but few larvæ reached the second stage.

No field observations were made.

Pear (*Pyrus communis* L.).

Pear foliage will sustain life in the gipsy-moth larvæ and carry them through to the adult, as shown by Mr. Collins's experiments at Worcester, but the larvæ and adults were very small and weak.

In the field but very little feeding has been noted on this foliage.

Persimmon (*Diospyros virginiana* L.).

This is not a favorable food plant, as but very few larvæ passed from one stage to the next stage, and growth was very slow.

No field observations.

Pitch Pine (*Pinus rigida* Mill.).

In the tray experiments no adults were obtained from larvæ started before the fourth stage, but from this stage both male and female moths were produced.

In the field the observers note feeding by the fourth, fifth, and sixth stage larvæ when pitch pine is growing with gray birch. The feeding is mostly confined to the old needles, the new growth seldom being attacked.

Red Pine (*Pinus resinosa* Ait.).

In the tray work with this species almost no feeding was observed until larvæ in the third stage were placed upon it. These, however, did not live beyond the fourth stage. The feeding was done by eating notches in the old needles.

In the field, larvæ were seen to feed upon red pine from the third to the sixth stages. In the last three stages they sometimes cause severe stripping.

Scotch Pine (*Pinus sylvestris* L.).

Tray experiments started with first-stage larvæ on this species failed to produce second-stage larvæ. Those started with second-stage produced sixth-stage larvæ, when many died from disease. The feeding was slow until the new growth expanded, after which they fed freely.

Mr. Proctor has noted practically the same thing in the field.

Gray Pine (*Pinus banksiana* Lamb.).

First-stage larvæ started on this foliage in the trays failed to go beyond the second stage. Trays started with larvæ in the third stage produced both male and female pupæ. Feeding was fairly free on the foliage after the first stage.

No field observations were made on this pine.

Western White Pine (*Pinus monticola* Dougl.).

First-stage larvæ supplied with this foliage failed to reach the second stage, but second-stage larvæ fed and a good number of male moths were produced. The feeding after the first stage was quite free, and this food seems to be more favored than the white pine.

No field observations were made on this pine.

White Pine (*Pinus strobus* L.).

Tray experiments show that first-stage larvæ can not feed to any extent upon the foliage and do not pass into the second stage. Mr. Collins succeeded in rearing adults from second-stage larvæ at Worcester on white pine.

In the field, where the pine is clear or in mixture with hemlock, feeding did not begin before the third or fourth stages. When the pine is mixed with gray birch or with any of the oaks, first and second stage larvæ were observed feeding to a slight extent.

The larva begins feeding near the base of the needle and eats through until the larger part falls to the ground. Other needles are attacked in the same way, so that a tree may be stripped in a very short time. (Pl. VI.)

Beach Plum (*Prunus maritima* Wang.).

Beach plum is not a particularly favored food plant. First-stage larvæ died before completing the third stage, and those started in the third stage produced male moths only. They fed but little, grew very slowly, and the pupæ were of small size.

Mr. Kennedy observed larvæ in the first, second, and third stages feeding upon this foliage to a slight extent in the field.

American Aspen (*Populus tremuloides* Michx.).

Although this species can not be placed in the class with oak, apple, willow, etc., in favorability, yet it will support the larvæ from time of hatching to pupation, and will produce fairly vigorous pupæ. The male moths developed from experiments when larvæ were started in the first stage.

Feeding was observed in the field by all stages, and in some cases complete defollation resulted.

BALM-OF-GILEAD (*Populus balsamifera* L.).

In the trays the food withered badly, and although first-stage larvæ developed full-grown larvæ and moths they were undersized.

In the field the writer has observed very large sixth-stage larvæ feeding on this poplar, and large adults resulted.

LARGE-TOOTHED ASPEN (*Populus grandidentata* Michx.).

No adults were obtained from the trays started with first-stage larvæ on this species, as the last caterpillar died in the fifth stage. The larvæ fed freely up to the fourth stage, when feeding fell off and they died rapidly of disease.

In the field much the same observations were made, but the larvæ were exceptionally large and some moths were produced.

LOMBARDY POPLAR (*Populus nigra* var. *italica* Moench).

No adults were obtained from this species either at Worcester or at Melrose Highlands, but at the former laboratory larvæ in the fifth stage developed in trays started in the first stage. Feeding was quite free on this species, but the larvæ died rapidly of disease.

No field observations were made.

SILVER POPLAR (*Populus alba* L.)

Both at Worcester and Melrose Highlands the larvæ started in the first stage on this foliage all died by the time they reached the fifth stage. They fed quite freely, but died rapidly of disease.

This species is not favored by the gipsy moth as are the other poplars.

PRIVET (*Ligustrum vulgare* L.)

Very few larvæ started in any stage on this foliage reached the succeeding stage.

Mr. Schaffner reports slight feeding by second, third, and fourth stage larvæ. It is an unfavored species.

RASPBERRY (*Rubus* sp.).

Several observers have records of feeding on this plant. Most of these are of larvæ in the first stages. Complete defoliation occasionally results.

PASTURE ROSE (*Rosa virginiana* Mill.).

A large percentage of adults were reared from trays started with first-stage larvæ fed upon this foliage. Heavy feeding occurs in all stages.

Records of field observations show that the larvæ feed freely in all stages when the infestation is fairly heavy and stripping has been noted.

WILD SARSAPARILLA (*Aralia nudicaulis* L.).

Sarsaparilla is a plant which is very common in some localities. No feeding has been found on its foliage by the gipsy-moth larvæ.

SASSAFRAS (*Sassafras sassafras* [L.] Karst.).

A few male moths were produced in trays started with first-stage larvæ on this foliage. Feeding was fairly heavy in all stages. This foliage was very hard to keep in a fresh state and the trays had to be changed frequently.

Field observers have recorded feeding in all stages and in some instances defoliation.

SERVICE-BERRY (*Amelanchier canadensis* [L.] Medic.).

This is a very favorable food plant as the tray experiments and the observations in the field show. The trays produced a good percentage of males and females. The larvæ grew rapidly and were of large size.

Field observers record the feeding of the larvæ in all stages and in some cases a complete defoliation.

SKUNK CABBAGE (*Spathyema fœtida* [L.] Raf.).

Mr. Kennedy found fourth and fifth stage larvæ feeding upon this species, and they continued into the sixth stage. Many of the leaves were badly eaten.

BLACK SPRUCE (*Picea mariana* [Mill.] B.S.P.).

No field observations were made on this species.

In the trays, first-stage larvæ were reared to adults on this foliage. During the first stage, growth was very slow and many died of starvation, but in the second stage feeding increased and continued to increase with each successive stage. The larvæ in the last stages were large and fed ravenously.

NORWAY SPRUCE (*Picea abies* [L.] Karst.).

From trays started with third-stage larvæ, adult moths were reared. Larvæ in all the lower stages died before reaching the next stage. In the later stages feeding was rapid, but in the first three stages the larvæ fed very little and growth was very slow.

RED SPRUCE (*Picea rubens* Sargent).

Trays started with first-stage larvæ on this foliage did not produce second-stage larvæ; when started with second-stage, male moths were produced only. In the first stage no feeding could be found on the foliage, and in the next stages feeding and growth were slow. In the last stages, however, the larvæ fed ravenously and growth was much faster.

WHITE SPRUCE (*Picea canadensis* (Mill.) B.S.P.).

The second stage produced a small percentage of male moths, and no females with larvæ started in trays on this foliage. Those started in the first stage died before reaching the second stage. In the later stages feeding was fairly heavy and growth was rapid. It is about the same in favorability as red spruce.

MOUNTAIN SUMAC (*Rhus copallina* L.).

This is one of the most favorable foods for all stages of the larvæ. A good percentage of males and females were reared from first-stage larvæ in the trays and growth was rapid.

All stages have been observed feeding upon it in the field, and defoliation has been noted repeatedly.

Scarlet Sumac (*Rhus glabra* L.)

This is another favorable species, and the larvæ grew to very large size. The first stage began feeding on the swelling buds by eating a small hole through the scales, and as the milky sap began to flow the larvæ fed upon it. They did not move about very much, but grew rapidly.

Feeding has been observed by all stages in the field.

Staghorn Sumac (*Rhus hirta* [L.] Sudw.).

This is not as favorable a species as the two foregoing. The larvæ do not grow as large. They will, however, develop from the first stage, but are badly attacked by disease.

All stages feed upon it in the field.

Red Gum (*Liquidambar styraciflua* L.).

This species ranks high as a favored food plant. Larvæ fed freely in all stages and grew rapidly. In the last two stages, however, they were badly affected by disease.

No field observations are available.

Sweet Pepperbush (*Clethra alnifolia* L.).

Field records show very slight feeding by all stages of the larvæ that have dropped from the overhanging trees, but they soon moved to other food.

In the trays no adults were obtained by starting any stage on this foliage until the fifth stage was reached, and then males were produced. It is a very unfavored food plant.

Sycamore (*Platanus occidentalis* L.).

Very few field records have been obtained on this species, although the second and third stages have been seen feeding very slightly on it.

In the trays the foliage was apparently very distasteful to them, and there was but little feeding and growth. Third-stage larvæ were reared to a few male moths. It is an unfavored species.

Tulip Tree (*Liriodendron tulipifera* L.).

Each successive stage was tried in the trays containing this foliage, both at Worcester and Melrose Highlands, but none reached the adult stage until experiments were begun with fifth-stage caterpillars. Scarcely any feeding was observed after the bud scales and blossoms dropped.

No field observations were made.

Black Gum (*Nyssa sylvatica* Marsh).

In the trays adults were reared from second-stage larvæ on this foliage, but all were males. In the first stage but very little feeding could be found on the leaves, and the larvæ did not reach the second stage.

In the field all stages were observed feeding upon the foliage, but no bad stripping was noted until the later stages.

Maple-leaved Arrowwood (*Viburnum acerifolium* L.).

This viburnum is not favored by the gipsy-moth larvæ in any stage, as shown by the field observations and the tray work.

In the trays none reached the adult stage, and nearly all the larvæ died in the stage in which the experiment was started.

In the field many larvæ in all stages were noted upon the foliage, having dropped from the overshadowing trees, but very little feeding was seen.

Arrowwood (*Viburnum dentatum* L.).

This foliage is somewhat more favorable as a food for gipsy-moth larvæ, as those started in the second stage reached the fifth stage, but no pupæ were obtained.

In the field but few observers had opportunity to obtain notes on this species. They have made record of slight feeding in nearly all stages.

Sweet Viburnum (*Viburnum lentago* L.).

The foliage of *lentago* is more readily eaten by gipsy-moth larvæ than the foregoing species. A few larvæ started in the early stages passed into the next stage, and male adults were obtained from trays started with fourth-stage larvæ. Growth was very slow and all were of small size.

No field observations were made on this species.

Cranberry Tree (*Viburnum opulus* L.).

Field observations show slight feeding by the larvæ in nearly all stages.

No tray experiments were conducted with this species.

Appalachian Tea (*Viburnum cassinoides* L.).

No pupæ were obtained from experiments with this species in the trays. The first-stage larvæ died after reaching the third and fourth stages, and the second-stage experiments were closed in the fifth and sixth stages.

In the field no feeding was observed except a few small notches in the leaves.

Black Walnut (*Juglans nigra* L.).

Tray experiments started with first-stage larvæ produced fifth-stage larvæ before they finally died. In the earlier stages very little feeding was done, but it increased considerably in the later stages. It is not a favorable food plant.

No field observations were made.

White Willow (*Salix alba* L.).

This is among the most-favored food plants for the gipsy-moth larvæ. In the trays a good number of adults of both sexes were obtained.

In the field all stages were observed feeding on the foliage, and large larvæ, adults, and egg masses were produced.

Glaucous Willow (*Salix discolor* Muhl.).

This species is also a favored food plant. In the trays a good number of adults were obtained from first-stage larvæ, which grew rapidly and were of large size.

No field observations were made.

BAY-LEAVED WILLOW (*Salix pentandra* L.).

From trays started with first-stage larvæ only fourth-stage larvæ were produced before they all died. No adults were obtained until fifth-stage larvæ were started. The foliage was rather distasteful to them and growth was slow.

No field observations were made on this species.

SANDBAR WILLOW (*Salix interior* Rowlee).

Not as favored as the first two species, but more favored than the bay-leaved willow. Trays started with third-stage larvæ produced both male and female moths.

No field observations were made on this willow.

WITCH-HAZEL (*Hamamelis virginiana* L.).

From the field came reports of the feeding of gipsy-moth larvæ in all stages upon this foliage, but probably more freely in the first stages.

In the trays, adults were reared from first-stage larvæ, which fed steadily in all stages.

The results given indicate in a general way the susceptibility of the species concerned to gipsy-moth attack.

There is in some cases, at least, considerable variation in susceptibility of different trees of the same species.

During the summer of 1912 foliage from two willow trees (*Salix alba* L.) were tested in trays at Melrose Highlands. They were growing side by side on lowland near a brook and both were in vigorous condition. First-stage gipsy-moth larvæ were placed in trays on the foliage of each tree.

Those supplied with the foliage of one tree fed normally, grew rapidly, and in due time developed into large adults. The other lot grew very slowly and the larvæ were very small and small adults developed. Nearly three times as many eggs were secured from the first lot as from the second. All the larvæ used in the experiment hatched from the same egg cluster.

In 1913 foliage from the same trees and larvæ hatched from the eggs of the previous year were used and the results were exactly reversed.

This indicates that there is variation in results with the same species of tree, but in this case it was not constant. A number of experiments along this line are contemplated.

COMBINATION-TRAY EXPERIMENTS.

Several series have been conducted to determine feeding preferences of gipsy-moth larvæ when two species of foliage were supplied in the same tray. In deciding the combination of species to be used it was thought best to place in the trays species that are usually found growing together in the field.

The results given below have been compared with the results with the same food plants growing in the open in so far as this data is available.

Speckled Alder and Willow.

Larvæ fed on both species, but appeared to prefer alder in all stages. After the foliage on alder was nearly all eaten the larvæ attacked the willow.

More adults were reared from these trays than from either alder or willow when fed alone. The larvæ grew steadily and attained large size.

In the field both alder and willow, when growing together, are defoliated if the infestation is heavy. The alder is usually stripped first.

American Beech and Chestnut.

Larvæ fed freely on the beech in the first two and last two stages. In the first stage there was no feeding on chestnut, and during the second stage the feeding was light, increasing to free in the third and fourth. After the fourth stage feeding decreased on chestnut. Preference for beech was noted except in third and fourth stages.

Larvæ grew to medium size and a fair percentage reached the adult stage.

American Beech and Red Oak.

Both of these foods were eaten freely throughout the experiment. Oak was a decided favorite in the first five stages. In the sixth stage feeding decreased, as the larvæ preferred the more tender leaves of the beech. The larvæ grew rapidly and were of large size. A good percentage reached the adult stage.

In the field the larvæ fed on the beech in the first two stages, then changed to the oak, where they fed until the last stage, when they returned to the beech.

American Beech and Sugar Maple.

Both these food plants were fed upon freely until the fifth stage, then moderately. A slight but continued decrease was noted on maple from the beginning of the fifth stage to the closing of the trays. Very little preference was observed in the first four stages.

A few larvæ reached the adult stage.

Black Birch and Witch Hazel.

There was no feeding on the birch during the first stage and but very little in the second and third. In the fourth and fifth stages the larvæ preferred the birch. The larvæ fed freely on witch hazel in the early stages. The caterpillars were small and reproduction resulted from this experiment.

Gray Birch and Chestnut.

There was no feeding on the chestnut during the first stage, but a steady increase was noted thereafter. Feeding was constant on the gray birch in all stages.

The larvæ grew slowly and were of small size and but few reached the adult stage.

Gray Birch and White Pine.

The larvæ fed freely in all stages on gray birch, but none at all on the pine in the first stage. The feeding on the latter species gradually increased until, in the last stages, they fed as well on this foliage as on the birch. They grew well and attained normal size and several reached the adult stage.

In the field in areas having this combination, the larvæ fed on the birch during the first three stages, when they attacked the pines. These were defoliated in many cases in the last three stages. The prevalence of wilt in the field often exerts a powerful influence in preventing complete defoliation of pine when it is grown in this combination.

Gray Birch and Red Spruce.

During the first stage all of the feeding was on the gray birch. There was a slight increase in feeding on the spruce in the later stages until the last two, when it diminished on the spruce.

The larvæ were rather small in size and grew slowly. A few reached the adult stage.

Paper Birch and Hemlock.

The larvæ fed freely on the paper birch in all stages. No feeding was noted on hemlock in the first stage, light in the second, and increasing during the third, and continuing moderate until the trays were closed. The larvæ showed a preference for birch in all stages, grew steadily to large size, and a large number of male and female moths developed.

Paper Birch and Sugar Maple.

The sugar maple in combination with this species is a favorable food. The larvæ fed upon it freely from the first to the fifth stages. During the fifth and sixth stages it was eaten more moderately. Birch was eaten freely at all times, although preferred in the later stages. Both species were eaten equally in the earlier stages.

The larvæ were of medium size and several reached the adult stage.

Paper Birch and Large-toothed Aspen.

Both of these foods are favorable. Except in the first stage, when the poplar was preferred, the larvæ fed with the same degree of freedom upon each. They grew steadily in the first stage, but more rapidly in the remaining stages, and attained average size. Several developed into adults.

Paper Birch and Red Spruce.

Larvæ fed freely on the birch in all stages, but did not feed on the spruce in the first stage. Feeding increased from the beginning of the second stage to the end of the fifth. Medium-sized larvæ resulted, from which several adults developed.

Paper Birch and Witch-hazel.

The larvæ fed freely on both food plants, with slight preference for witch-hazel until near the end of the experiment, when birch was eaten more freely.

Large larvæ resulted, from which several adults developed.

Yellow Birch and Hemlock.

Larvæ fed on the birch freely in the first four stages and more moderately in the latter stages. No feeding occurred on hemlock in the first and second stages. It was slight in the third and continued light in the remaining stages.

Larvæ grew rather slowly and were of small size and a few changed to adults.

Yellow Birch and Red Maple.

Larvæ fed more freely on birch than on maple, and the same proportionate feeding was maintained throughout the experiment. They were of small size and were badly attacked by disease. A small number reached the adult stage.

Yellow Birch and Sugar Maple.

The larvæ fed moderately on both food plants, with a slight preference for the birch at times. They grew slowly and were of moderate size. A few males and females were obtained.

Yellow Birch and Witch-hazel.

There was moderate feeding on both these food plants, but at times some preference was shown for witch-hazel. Growth was rather slow and the larvæ attained moderate size. A few males resulted.

Low Blueberry and White Pine.

This is the most unfavorable of the blueberries. Feeding was very light in the early stages and increased later, but at no time was this plant eaten freely. There was no feeding on pine in the first three stages. It was light in the fourth and increased in the later stages. Larvæ grew slowly in the early stages, but much more rapidly later, and reached medium size. Only males were obtained.

In a single location in the field the blueberry was very slightly eaten by first-stage larvæ, but no feeding was noted by the later stages. The infestation was light and no defoliation resulted to either the blueberry or pine.

Tall Blueberry and White Pine.

The feeding on blueberry by the first and second stage was light and there was great variation in the rapidity of growth. In the remaining stages feeding was free. Pine was not eaten in the first two stages. In the other stages it was fed upon slightly, but not freely. The larvæ grew quite rapidly and reached medium size. Adults of both sexes were obtained.

Blueberry and White Pine.

This blueberry is the most favored of the blueberries, and larvæ fed freely upon it in all stages. Pine was not eaten at all in the first two stages, but feeding increased in the later stages, when it was often eaten from choice. The larvæ grew rapidly and attained average size, and males and females developed.

Field reports show nearly complete stripping of the blueberry, but almost no injury being done to the pines.

Southern White Cedar and Red Maple.

Maple feeding was very light in the first stage; a gradual increase in the ensuing stages, which was never more than moderate. Cedar was not eaten in any stage even when the maple was in a withered condition. The growth of the larvæ varied greatly in this experiment.

In Middleboro, Mass., a large area in a swamp where these species predominate has been under observation for several years. During some seasons both the maples and the cedars have been defoliated, the latter by the large larvæ.

The small amount of undergrowth and the few other species of trees are unfavored food for gipsy-moth larvæ, and in this case practically all the feeding has been confined to the two species under discussion. This field record furnishes information which is quite contradictory to the laboratory experiments, although such evidence is exceptional.

American Hornbeam and Red Oak.

Feeding was continuous in all stages on the oak, but was very slight on the hornbeam in the first two stages, but later was much greater. A decided preference for oak was shown in all stages. The larvæ grew steadily and attained large size. A good percentage reached the adult stage.

Hophornbeam and Red Oak.

The larvæ fed freely in all stages on the oak, and the feeding increased from slight at the start to moderately free on hornbeam at the close of the experiment. Larvæ grew rapidly and attained large size and a good percentage reached the adult stage.

American Linden and Red Maple.

The larvæ fed moderately on the maple throughout the experiment. Linden feeding was moderate in the first stage, falling off slightly in the second and third, and moderate in the remaining stages. The larvæ were of good size and a fair percentage of adults was obtained.

Elm and White Pine.

None of the first-stage larvæ started on these food plants passed beyond the third stage. They fed only on the elm and were of very small size. Those started in the third stage produced male and female moths. They fed slowly on these foods, and grew accordingly.

In the field there has apparently been a steady decrease in the infestation, the pines being eaten by the large larvæ.

Hemlock and American Linden.

Larvæ fed freely on linden in all stages and very slightly on hemlock in the second stage. Feeding increased on the latter species in each successive stage. The larvæ attained moderate size, and a few adults were reared.

Hemlock and Sugar Maple.

There was no feeding on the hemlock during the first stage, but it increased gradually from the second to the sixth stage. Feeding was moderate on maple during the whole experiment. The larvæ reached medium size, and a few adults of both sexes were obtained.

Hemlock and Witch-hazel.

The larvæ fed freely in all stages on the witch-hazel, but none at all on the hemlock in the first stage; feeding increased gradually, and in the three last stages hemlock foliage was eaten freely.

The larvæ were of good size and produced both male and female moths.

Chestnut and Red Maple.

No feeding was apparent on the chestnut during the first and second stages, and it was moderate in the remaining stages. Feeding on maple was moderate in all stages. The larvæ were below average size, grew slowly, and only males developed.

In the field similar results have been observed.

Chestnut and Black Oak.

The larvæ fed freely on both food plants, except in the first stage, when they attacked oak exclusively. They grew steadily, attained large size, and adults were reared.

Field observations indicate that these species are freely eaten when growing in the same locality.

Chestnut and Chestnut Oak.

The oak was fed upon freely in all stages, but the chestnut was eaten moderately in all stages except the first. Growth was slow and the larvæ died before pupating.

Chestnut and White Pine.

Larvæ started in the first stage died in the third stage or earlier. Those that molted once were very small and puny, while those started in the third stage produced a few male moths. Both plants were eaten quite freely in the last stages.

Similar results have been noted in the field.

American Linden and Red Oak.

The larvæ fed lightly on the linden in the first few stages, and, although the feeding increased slightly in the later stages, it was never excessive. Oak was preferred and was eaten freely in all stages. The larvæ developed rapidly, were of average size, and several moths were reared.

In the field this combination furnishes very favorable food for the gipsy moth.

Red Maple and Witch-hazel.

The larvæ fed freely on both food plants in the first two stages, but from the end of second stage to the close of the experiment a preference was shown for witch-hazel.

The larvæ grew rather slowly and but few adults were obtained.

White Pine and Witch-hazel.

The larvæ fed moderately on witch-hazel in all stages, but none on pine during the first two stages. Later the feeding increased steadily to the end of the experiment.

The larvæ were of small size and but few adults were reared.

POPLAR AND RED SPRUCE.

The larvæ fed freely on the poplar in all stages, but very slightly on the spruce, no feeding being noted in the first two stages. They grew steadily and to fairly large size, and a small number reached the adult stage.

CLASSIFICATION OF FOOD PLANTS.

As a result of the experiments with single food plants and combinations, it is possible to draw up a classification of the trees and shrubs tested as regards their susceptibility to attack by the gipsy moth.

They have been arranged in the following classes:

Class I. Species that are favored food for the gipsy moth.

Class II. Species that are favored food for the gipsy moth after the early larval stages.

Class III. Species that are not particularly favored, but upon which a small proportion of the gipsy-moth larvæ may develop.

Class IV. Species that are unfavored food for the gipsy moth.

CLASS I.—*Species that are favored food for the gipsy-moth larvæ.*

Alder, Spreckled.
Apple.
Ash, Mountain.
Aspen, American.
Aspen, Large-toothed.
Balm-of-Gilead.
Beech, American.
Birch, Gray.
Birch, Paper.
Birch, Red.
Blueberry (V. *angustifolium*).
Box Elder.
Gum, Red.
Hawthorn.
Hazelnut.
Hazelnut, Beaked.
Larch, American.
Larch, European.
Linden, American.
Linden, European.
Oak, Black.
Oak, Rock Chestnut.
Oak, Dwarf Chestnut.
Oak, Bur.
Oak, Pin.
Oak, Post.
Oak, Red.
Oak, Scarlet.
Oak, Bear.
Oak, Shingle.
Oak, Swamp White.
Oak, White.
Poplar, Lombardy.
Rose, Pasture.
Service-berry.
Sumac, Mountain.
Sumac, Scarlet.
Sumac, Staghorn.
Willow, White.
Willow, Glaucous.
Willow, Sandbar.
Witch-hazel.

CLASS II.—*Species that are favored food for gipsy-moth larvæ after the earlier larval stages.*

Chestnut.
Hemlock.
Pine, Pitch.
Pine, Red.
Pine, Scotch.
Pine, Jack.
Pine, Western White.
Pine, White.
Plum, Beach.
Spruce, Black.
Spruce, Norway.
Spruce, Red.
Spruce, White.

CLASS III.—*Species that are not particularly favored but upon which a small proportion of the gipsy-moth larvæ may develop.*

Barberry, European.
Bayberry.
Birch, Black.
Birch, Yellow.
Blueberry, Low.
Blueberry, Tall.
Cherry, Sweet.
Cherry, Wild Black.
Cherry, Wild Red.
Chokeberry.
Choke Cherry.
Cottonwood.
Cranberry, American.
Elm, American.
Elm, European.
Elm, Slippery.
Fern, Sweet.
Gale, Sweet.
Gum, Black.
Hickory, Bitternut.
Hickory, Mockernut.
Hickory, Pignut.
Hickory, Shagbark.
Hornbeam, American.
Hophornbeam.
Maple, Norway.
Maple, Red.
Maple, Silver.
Maple, Sugar.
Pear.
Poplar, Silver.
Sassafras.

CLASS IV.—*Species that are unfavored food for gipsy-moth larvæ.*

Arbor Vitæ.
Arrowwood.
Arrowwood, Maple-leaved.
Ash, Black.
Ash, Blue.
Ash, Red.
Ash, White.
Azalea, White and Flame.
Balsam, Fir.
Blackberry, High.
Blue-flag, Larger.
Butternut.
Catalpa, Hardy.
Cedar, Red.
Cedar, Southern White.
Cornus.
Cranberry-tree.
Currant, Red.
Cypress, Bald.
Dangleberry.
Dock, Narrow.
Dogwood, Flowering.
Elder, American.
Eubotrys, Swamp.
Feverbush.
Grape.
Greenbrier.
Hackberry.
Hardhack, Pink.
Hardhack, White.
Holly, American White.
Honeysuckle, Bush.
Huckleberry, Highbush.
Inkberry.
Ivy, Poison.
Juniper, Common.
Kentucky Coffee-tree.
Laurel, Mountain.
Laurel, Sheep.
Locust, Black.
Locust, Honey.
Maple, Mountain.
Maple, Striped.
Mulberry, Red.
Mulberry, White.
Osage Orange.
Osier, Red.
Pepperbush.
Persimmon.
Privet.
Raspberry.
Sarsaparilla.
Skunk Cabbage.
Spice-bush.
Sweetbrier.
Sweet Pepper-bush.
Sycamore.
Tea, Appalachian.
Tulip-tree.
Viburnum, Sweet.
Walnut, Black.
Willow, Bay-leaved.
Winterberry, Smooth.

In arranging the foregoing classes it was not easy in all cases to assign a food plant according to this arbitrary classification. A number of species such as the poplars and hickories belong near the border line of Classes I and II, and they have been rated in the list which seems most appropriate. In general it can be said that whenever any of the trees or shrubs in Class IV are growing together no injury from gipsy-moth attack need be feared, and the same is true of Class II, or a combination of Classes II and IV. In case any of the species given in Class III are present there is a slight chance of injury resulting, but for practical purposes no difficulty is likely to be experienced by an owner so long as the species given in Class I are not present in his woodland or on his private grounds.

THE FOREST PROBLEM.

An examination of these classes, however, shows that the species noted in Class I are at present the dominant species in the woodlands in the area now infested with the gipsy moth. The oaks and birches predominate over much of this area, and this increases the difficulty of remedying the situation.

It will be noted that most of the species of high commercial value are included in Classes I and II. In arranging combinations which will resist moth attack it is necessary to consider the soil and other conditions suitable for their successful growth and to endeavor to bring about replacements with the least possible expenditure of money.

The encouragement of coniferous growth is to be commended provided the Class I trees can be eliminated. Experimental work with different stands of forest growth is being conducted by Mr. G. E. Clement, of the Bureau of Entomology, and practical advice to owners conveying the best methods of handling their wooded areas is being furnished.

It should be noted in examining the foregoing lists that, in addition to forest trees and shrubs, plants of much importance to horticulture and for ornamental and city planting are included. The problem is therefore broader than that of managing forests, as horticultural and shade-tree management should be adopted so that the least injury will result from the moth and that the least expense in controlling it will be necessary.

RECOMMENDATIONS FOR ORCHARD PRACTICE.

Among the horticultural crops most likely to be affected by the gipsy moth is the apple.

In moderate infestations the gipsy moth can be controlled by spraying with arsenate of lead, used at the rate of 10 pounds to 100

gallons of water. It should be applied as soon as the trees come into full leaf and will assist materially in controlling the codling moth. Improved methods of management and care of the trees will do much to decrease the danger from this pest. Hollow trees should be filled or cut, and all rubbish that will furnish convenient quarters in which the moths may deposit their eggs should be cleaned up and burned.

If the orchard infestation is serious, creosoting egg clusters and banding the trees with tanglefoot may be necessary.

During the past year a number of cases of severe injury to cranberries have been observed. This was caused by feeding of the caterpillars on the tender growth and cutting off the fruit buds and blossoms, which resulted in a serious decrease in the yield.

It is probable that this insect will not increase in sufficient numbers in cranberry bogs to kill the vines, and it has, therefore, been considered as able to survive on this plant (Class III). The money loss on account of diminution in yield is likely to be serious.

THE CITY PROBLEM.

On home grounds, in cities and parks, or on street or shade trees, this problem requires the expenditure of large sums of money if species favorable for the development of gipsy-moth caterpillars are to remain. Not only must the insect be reduced, so that injury to the trees will not result, but the caterpillar nuisance must be abated, particularly in the residential sections.

When future plantings are made, species should be selected which will not require a constant expenditure of money in order to keep them free from the moths. The lists given will furnish a guide in this respect.

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Grape (*Vitis labrusca* L.) 14
Greenbrier (*Smilax rotundifolia* L.) 10
Gum, Black (*Nyssa sylvatica* Marsh.) 25
Gum, Red (*Liquidambar styraciflua* L.) 25
Hackberry (*Celtis occidentalis* L.) 14
Hardhack, Pink (*Spiræa tomentosa* L.) 14
Hardhack, White (*Spiræa salicifolia* L.) 14
Hawthorn (*Cratægus* sp.) 14
Hazelnut (*Corylus americana* Walt.) 15
Hazelnut, Beaked (*Corylus rostrata* Ait.) 15
Hemlock (*Tsuga canadensis* [L.] Carr.) 15
Hickory, Bitternut (*Hicoria cordiformis* [Wang.] Britton) 15
Hickory, Mockernut (*Hicoria alba* [L.] Britton) 15

Page.
Hickory, Pignut (*Hicoria glabra* [Mill.] Britton) 15
Hickory, Shagbark (*Hicoria ovata* [Mill.] Britton) 15
Holly, American White (*Ilex opaca* Ait.) 16
Honeysuckle, Bush (*Diervilla diervilla* [L.] MacM.) 13
Hornbeam, American (*Carpinus caroliniana* Walt.) 16
Hop Hornbeam (*Ostrya virginiana* [Mill.] Willd.) 16
Huckleberry, Highbush (*Gaylussacia baccata* (Wang.) Koch 16
Inkberry (*Ilex glabra* [L.] A. Gray) 16
Ivy, Poison (*Toxicodendron radicans* [L.] Kuntze) 17
Juniper, Common (*Juniperus communis* L.) 17
Kentucky Coffee-tree (*Gymnocladus dioica* [L.] Koch) 17
Larch, American (*Larix laricina* [Du Roi] Koch) 17
Larch, European (*Larix decidua* Mill.) 17
Laurel, Mountain (*Kalmia latifolia* L.) 17
Laurel, Sheep (*Kalmia angustifolia* L.) 17
Linden, American (*Tilia americana* L.) 18
Linden, European (*Tilia* sp. L.) 18
Locust, Black (*Robinia Pseudoacacia* L.) 18
Locust, Honey (*Gleditsia triacanthos* L.) 18
Maple, Mountain (*Acer spicatum* Lam.) 18
Maple, Norway (*Acer platanoides* L.) 18
Maple, Red (*Acer rubrum* L.) 19
Maple, Silver (*Acer saccharinum* L.) 19
Maple, Striped (*Acer pennsylvanicum* L.) 19
Maple, Sugar (*Acer saccharum* Marsh.) 19
Mulberry, Red (*Morus rubra* L.) 19
Mulberry, White (*Morus alba* L.) 19
Oak, Bear (*Quercus ilicifolia* Wang.) 20
Oak, Black (*Quercus velutina* Lam.) 19
Oak, Rock Chestnut (*Quercus prinus* L.) 20
Oak, Dwarf Chestnut (*Quercus prinoides* Willd.) 20
Oak, Bur (*Quercus macrocarpa* Michx.) 20
Oak, Pin (*Quercus palustris* Du Roi) 20
Oak, Post (*Quercus stellata* Wang.) 20
Oak, Red (*Quercus rubra* L.) 20
Oak, Scarlet (*Quercus coccinea* Wang.) 20
Oak, Shingle (*Quercus imbricaria* Michx.) 21
Oak, Swamp White (*Quercus bicolor* Willd.) 21
Oak, White (*Quercus alba* L.) 21
Osage Orange (*Toxylon pomiferum* [Raf.]) 21
Osier, Red (*Cornus stolonifera* Michx.) 12
Pear (*Pyrus communis* L.) 21
Pepperbush (*Xolisma ligustrina* [L.] Britton) 18
Persimmon (*Diospyros virginiana* L.) 21
Pine, Gray (*Pinus banksiana* Lamb.) 22
Pine, Pitch (*Pinus rigida* Mill.) 21
Pine, Red (*Pinus resinosa* Ait.) 21
Pine, Scotch (*Pinus sylvestris* L.) 22
Pine, White, Western (*Pinus monticola* Dougl.) 22
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Spruce, Red (*Picea rubens* Sargent) 24
Spruce, White (*Picea canadensis* [Mill.] B.S.P.) 24
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Sumac, Scarlet (*Rhus glabra* L.) 25
Sumac, Staghorn (*Rhus hirta* [L.] Sudw.) 25
Sweetbrier (*Rosa rubiginosa* L.) 10
Sweet Pepperbush (*Clethra alnifolia* L.) 25
Sycamore (*Platanus occidentalis* L.) 25
Tea, Appalachian (*Viburnum cassinoides* L.) 26
Tulip Tree (*Liriodendron tulipifera* L.) 25
Viburnum, Sweet (*Viburnum lentago* L.) 26
Walnut, Black (*Juglans nigra* L.) 26
Willow, White (*Salix alba* L.) 26
Willow, Glaucous (*Salix discolor* Muhl.) 26
Willow, Bay-leaved (*Salix pentandra* L.) 27
Willow, Sandbar (*Salix interior* Rowlee) 27
Winterberry, Smooth (*Ilex lævigata* [Pursh] A. Gray) 16
Wintergreen (*Gaultheria procumbens* L.) 10
Witch-hazel (*Hamamelis virginiana* L.) 27

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 251

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER July 27, 1915.

THE CALOSOMA BEETLE (CALOSOMA SYCOPHANTA) IN NEW ENGLAND

By

A. F. BURGESS, In Charge of Gipsy Moth and Brown-tail Moth Investigations, and C. W. COLLINS
Entomological Assistant

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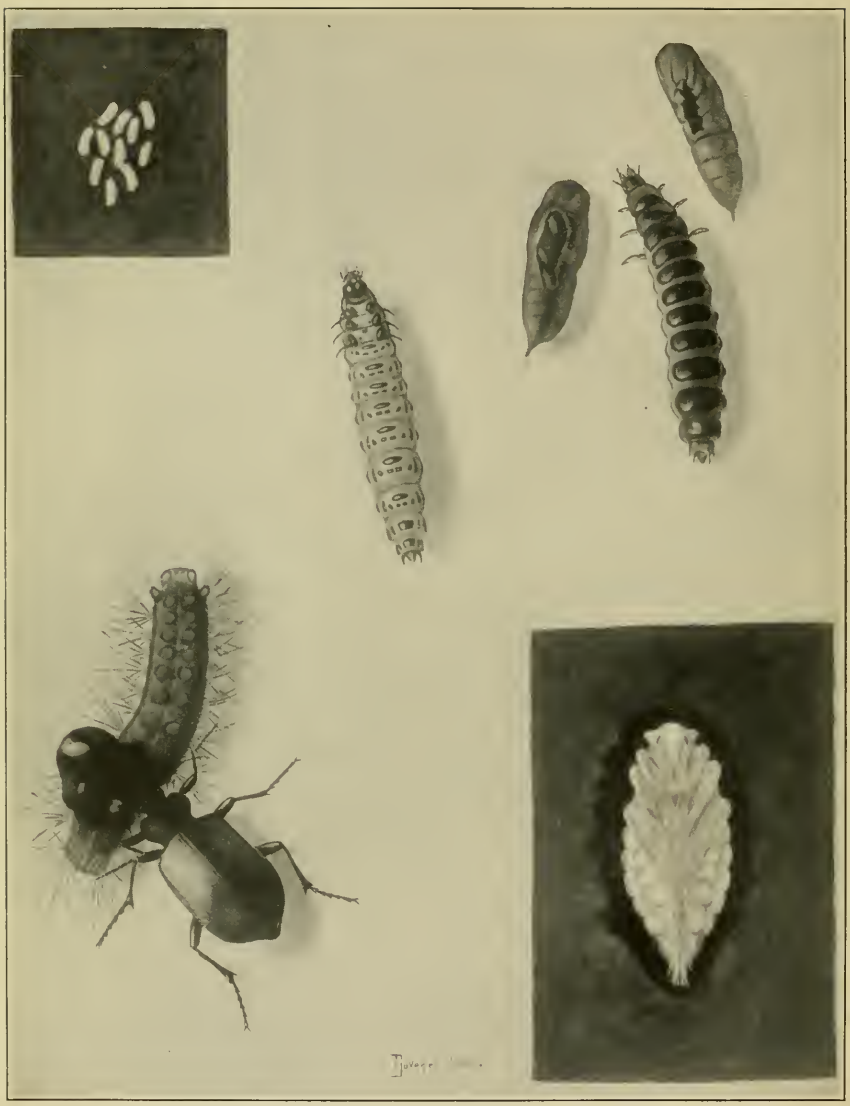

THE CALOSOMA BEETLE (CALOSOMA SYCOPHANTA).

Upper left, eggs; lower left, adult beetle feeding on gipsy moth caterpillar; upper right, gipsy moth pupæ destroyed by Calosoma larvæ; center, Calosoma larva, ventral view; right center, Calosoma larva, dorsal view; lower right, Calosoma pupa in cavity in ground. (From Howard and Fiske.)

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INTRODUCTION.

In the spring of 1905 an arrangement was made by the United States Department of Agriculture to cooperate with the State of Massachusetts in importing and establishing the natural enemies of the gipsy moth and the brown-tail moth. Dr. L. O. Howard, Chief of the Bureau of Entomology, supervised the work, and until December 1, 1911, this arrangement remained in force, the project being financed jointly by the Bureau of Entomology and the State of Massachusetts. Since 1912, owing to the fact that the scope of the work involved nearly all of the New England States, these projects have been carried on solely by the Bureau of Entomology.

One of the natural enemies of the gipsy moth, which has long been known in Europe as of prime importance, is a green beetle be-

Note.—The writers wish to acknowledge their obligation to the members of the staff at the Gipsy Moth Laboratory for securing data and carrying on many of the experiments which are only briefly alluded to in this publication. There is hardly a man who has been connected with the laboratory for the past seven years who has not assisted to a greater or less extent in obtaining information and securing some of the results already mentioned. So many have assisted in this work that it is impossible to name each individual, but the writers wish to express their appreciation to all those who have taken part in the work.

longing to the family Carabidæ, and known to science as *Calosoma sycophanta* L. (Pl. I.) This species was collected and shipped to Massachusetts, as a result of arrangements made by Dr. Howard with numerous European collectors of insects, more particularly with Miss Marie Rühl, of Zurich, Switzerland. Several other closely related species of Calosoma were collected and some of these were received in sufficient numbers to permit of colonies being liberated in woodland infested with the gipsy moth. Several species of the allied genus Carabus were obtained and similarly liberated.

Up to the present time the only species that is known to have maintained itself is *Calosoma sycophanta*, and this insect has increased so enormously as to become an effective enemy of the gipsy moth in this country.

Table I gives the number of live specimens of *Calosoma sycophanta* which have been imported from Europe. Sixty-seven per cent of these beetles were liberated in the field and the balance were used for experimental and reproduction work. All the beneficial results secured in the field have accrued from about 4,000 beetles noted in the table.

TABLE I.—*Number of living specimens of Calosoma sycophanta received from Europe.*

Year.	Number received.	Year.	Number received.
1905	1	1909	405
1906	693	1910	1,305
1907	967		
1908	675	Total	4,046

METHODS OF PACKING BEETLES FOR SHIPMENT.

Different plans covering the packing of these beetles for shipment were tested during the years above mentioned. The most satisfactory arrangement was to pack the beetles singly in small safety-match boxes which contained a quantity of wet sphagnum moss. These boxes were packed in a larger wooden box (fig. 1), the usual size being 7¼ by 4 by 2¼ inches. A shipping label was glued to the box. Material packed in this manner was shipped by mail and received in good condition. Experience has shown that the greatest cause of mortality in shipping these beetles is due to lack of moisture. When sufficient moisture is provided no difficulty is experienced, and it is not necessary to place food of any kind in the boxes. As a rule, these shipments were en route from 10 to 12 days. In case beetles are to be forwarded and will not be in transit more than 2 days, several can be placed in a box and shipped by ordinary mail with very little injury resulting.

NATIVE HOME OF CALOSOMA SYCOPHANTA AND HOSTS ATTACKED.

This insect is known to occur in France, Germany, Switzerland, Italy, and other European countries, being particularly abundant in cases where there are unusual outbreaks of destructive caterpillars. Its good work is mentioned in a number of European writings, and it is known to prey extensively on the gipsy moth (*Porthetria dispar* L.) and the pine sawfly (*Lophyrus pini* L.). As early as 1736 Reaumur published a general account of the life history of the species, and valuable information has been published by M. G. de la Pouge concerning his investigations of the larvæ of this insect.

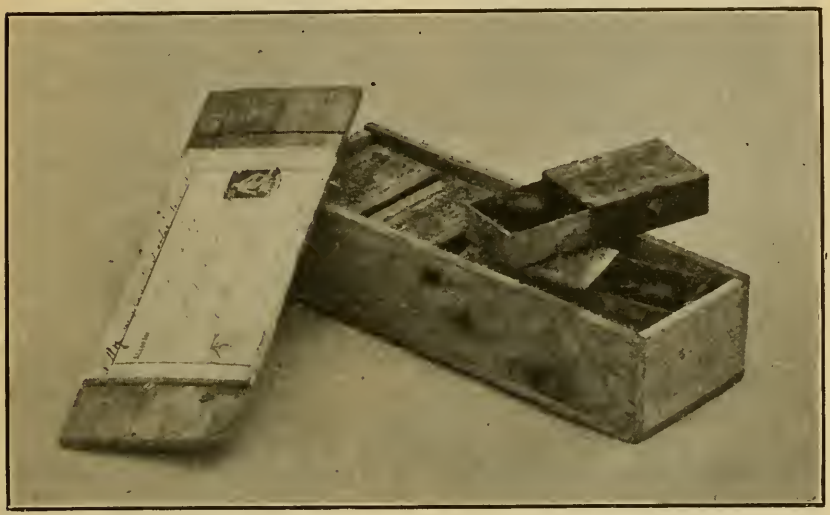


FIG. 1.—Shipping box, with cover removed to show method of packing Calosoma beetles. Each match box contains a single beetle and a small quantity of wet sphagnum moss. (From Burgess.)

INVESTIGATIONAL WORK ON CALOSOMA SYCOPHANTA.

The year 1906 was the first in which these beetles were received in large enough numbers that colonies might be liberated or a study made of their habits. During that year considerable work was carried on by Mr. E. S. G. Titus and Mr. F. H. Mosher, and notes and observations on the behavior of the species in large breeding cages were made by Mr R. L. Webster. During the following summer the work was placed in charge of the senior author, and since that time detailed experiments have been conducted. Mr. C. W. Collins has assisted with this work during the entire period and for the past two or three years has planned and executed many of the experiments.

EQUIPMENT USED FOR REARING PREDACEOUS BEETLES.

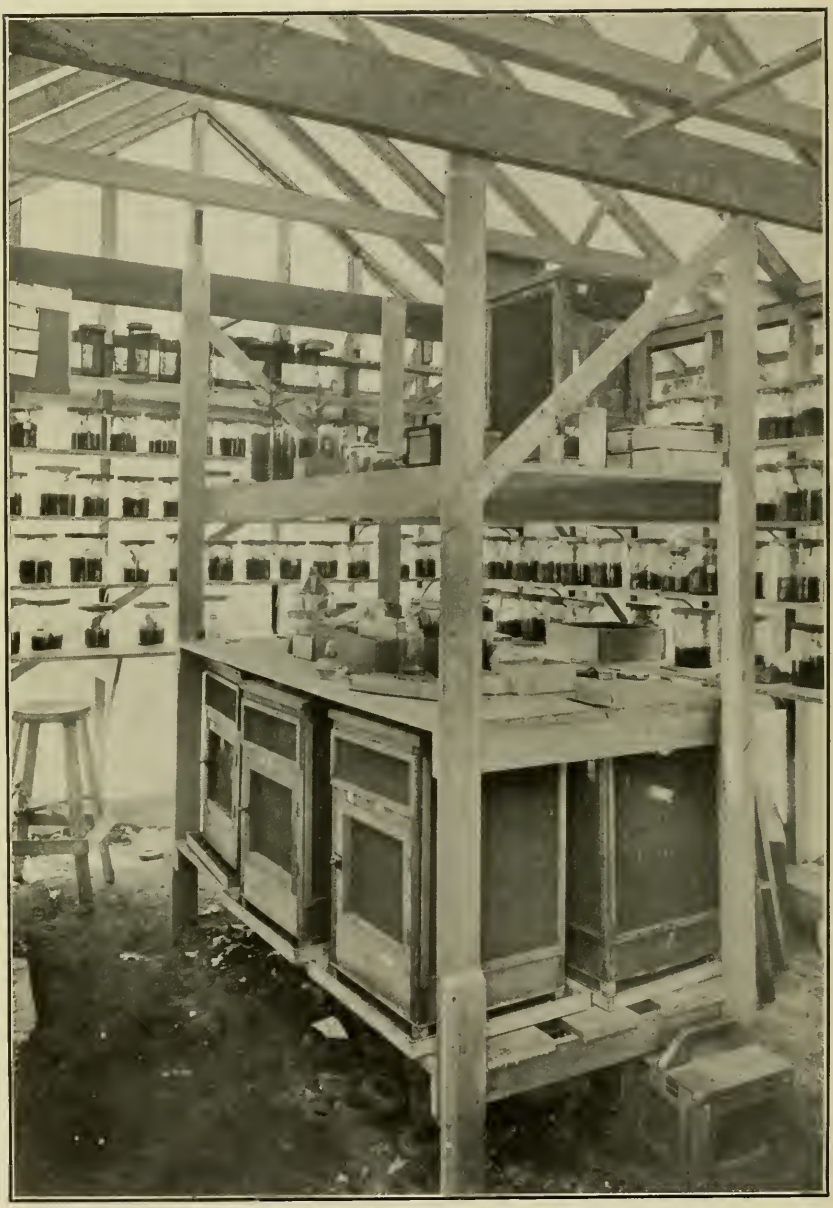
Experiments have shown that Calosoma beetles, in common with most other insects, thrive when they are kept under natural conditions. Fair success may be secured through rearing experiments in a laboratory, but as the beetles are most active, both concerning feeding and reproduction, during hot weather, and as it is important to regulate the soil moisture if best results are to be secured, it has been found decidedly advantageous to use an outdoor insectary for work of this description. An insectary such as is in use at the Gipsy Moth Laboratory, Melrose Highlands, Mass. (Pl. II), is inexpensive and will last a number of years. We have used a cement foundation on which was erected a frame constructed of 2 by 4 studding. The exterior walls have been covered with fine-mesh wire netting and the roof is canvas. A coating of white lead applied to the canvas will make it last longer, and if the netting walls are painted annually with black screen paint to prevent corrosion, they will not need to be renewed for two or three years. Copper-wire netting can be substituted for the walls and does not require paint. The insectary is provided with outside canvas curtains which may be rolled up in order to regulate the amount of sunlight or keep out rain; awnings could be used for this purpose if desired. Shelves, benches, or tables may be added as necessary. A building of this description fairly approximates outdoor conditions and has given very satisfactory service. (Pl. III.)

Beetles of this genus deposit their eggs in the ground. They also conceal themselves for a part of the time beneath litter or rubbish. The best results with *sycophanta* have been secured by using battery jars 8½ inches tall and 6½ inches in diameter (fig. 2), but a size slightly smaller will give as satisfactory results. Circular wooden tops are used to cover these jars, which are grooved to hold the top in place. A round hole, allowing air to pass into the jar, is cut in the center of the circular wooden top and is covered with wire netting. As *sycophanta* is a climbing species, but is unable to make its way up the smooth sides of the jars, a narrow strip of mosquito wire is attached to the inside of the top, so that it extends into the jar and gives the beetle an opportunity to climb to the top in search of caterpillars that are placed in the jar for food. About 3 inches of loam should be placed in each jar, and they are then ready for use

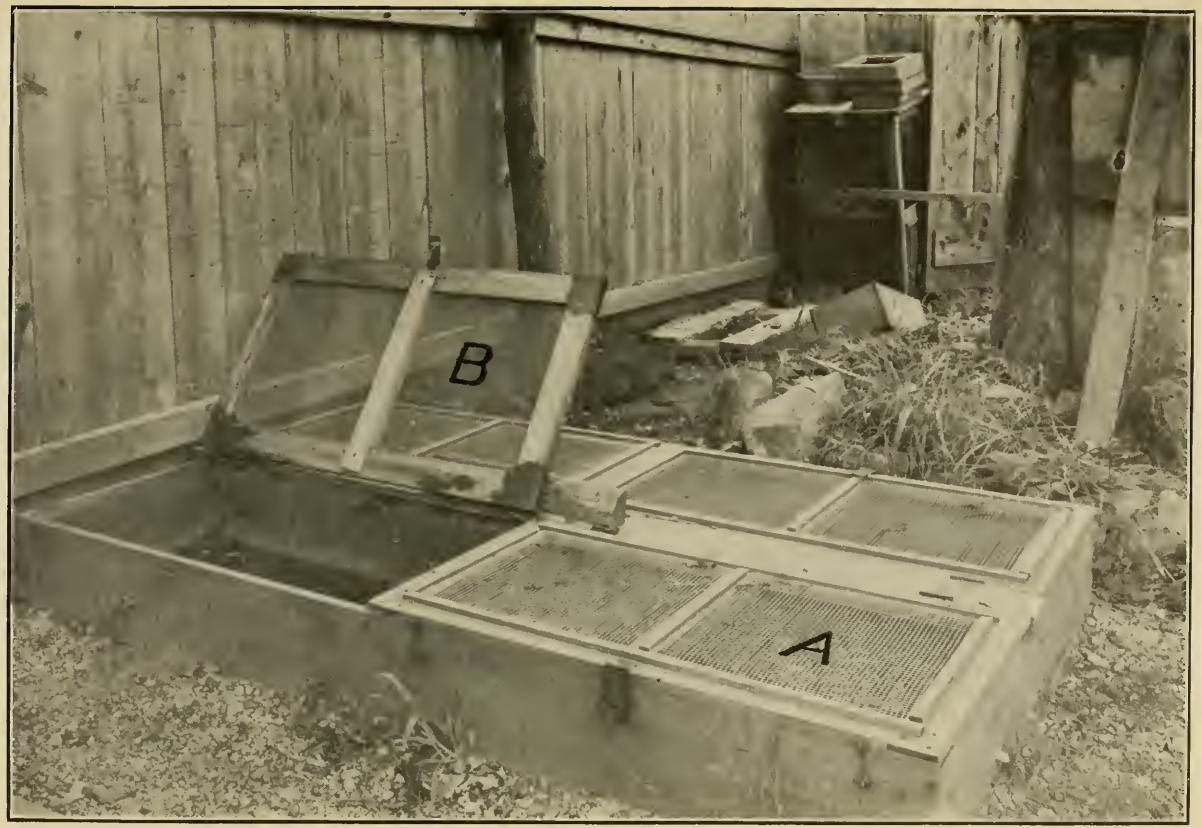
For rearing small larvæ of this species jelly tumblers containing earth and covered with cheesecloth can be used. The insects in this stage are cannibalistic, and it is therefore necessary to keep each larva in a separate jar if exact records are desired. Caterpillars or pupæ of almost any insect can be furnished for food and the soil must be kept slightly moist, but not wet. These larvæ can be reared

OUT-DOOR INSECTARIES FOR REARING CALOSOMA BEETLES.

A was built in 1909; *B* was built in 1910. (From Burgess.)



INTERIOR VIEW OF INSECTARY "*B*," SHOWN IN PLATE II. (FROM BURGESS.)



BOX CAGES USED FOR REARING CALOSOMA LARVÆ LATE IN THE SUMMER.

B, cover with fine-mesh screen, used in summer; *A*, showing coarse-mesh screen top, used after the larvæ have gone into the ground to transform and hibernate. (From Burgess.)

in wire cages if desired. The bottoms should be made of a circular piece of board 4 inches in diameter, having a hole in the center covered with netting. To the circumference of this base is tacked a strip of wire netting 10 inches in width. It should be cut long enough to lap at the side, so that it can be sewed with wire. The selvage edge of the wire netting should be used for the top of the cage and care should be taken that the circumference at the top and the bottom are the same. A cover similar to the ones used on the glass jars may then be placed on the top of the cage. These cages should be set 8 inches in the ground. After the larvæ become full grown they descend into the ground and form their pupal chambers Cages of this

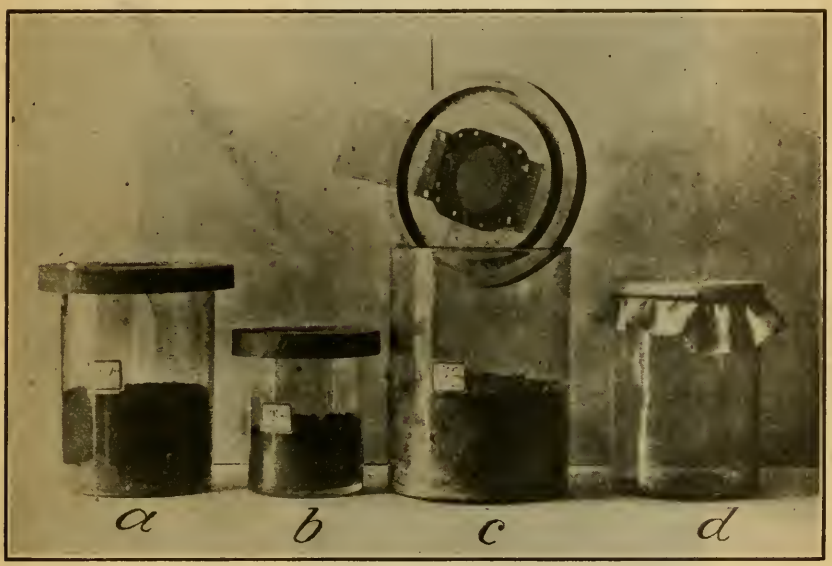


FIG. 2.—Jars for rearing Calosoma beetles: *a*, Large jar with wooden top and "ladder"; *b*, small jar with wooden top; *c*, showing construction of top and "ladder"; *d*, jar with cheesecloth top held in position with rubber band. (From Burgess.)

sort should not be disturbed until the following spring. For hibernating quarters for beetles, boxes with bottoms made of wire screen can be used (Pl. IV). They should be sunk into the ground from 18 to 20 inches, the earth inside the box being the same level as that on the outside. A hinged cover provided with wire netting should be placed on the top of the box and if convenient this cover should be padlocked so that the contents of the box will not be disturbed. Beetles may be placed in hibernation in cylinders (fig. 3) made of galvanized iron wire having a $\frac{1}{4}$-inch mesh. These can be constructed in the same manner as the small cylinders already mentioned. If larvæ are to be placed in these cylinders it will be necessary to line them with fine wire screen in order to prevent their escape. This

equipment has been selected as a result of many experiments and has been found to work very satisfactorily.

METHODS OF REARING CALOSOMA BEETLE.

The most satisfactory manner of rearing these insects, in case it is desired to secure definite records of the number of eggs laid by a single individual or the amount of food consumed, is to place a pair

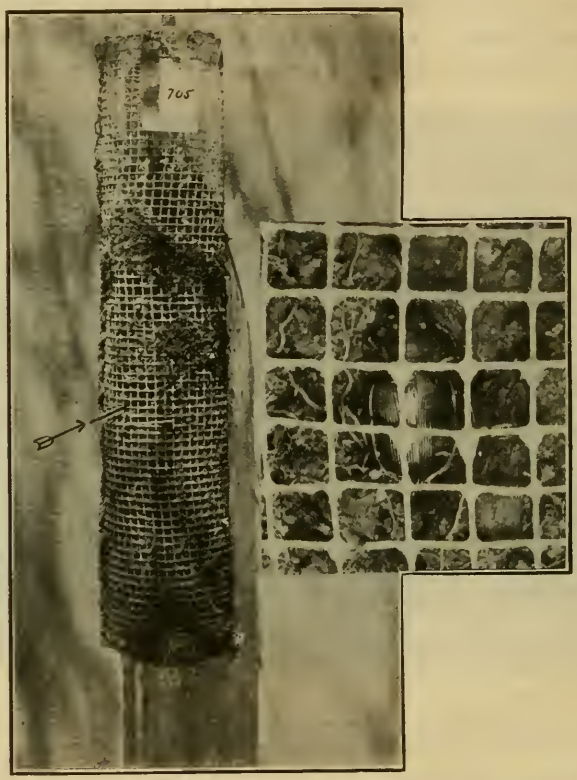


FIG. 3.—Wire hibernation cage that has been removed from the earth. Arrow shows the cavity where a Calosoma beetle hibernated; enlargement shows this beetle in the cage. (From Burgess.)

of beetles in one of the larger glass jars with a supply of caterpillars for food. The jars should be cleaned daily and all wounded or dead caterpillars removed. If this is not done, considerable difficulty is likely to be experienced. The earth should be examined daily, and if eggs are found the beetles should be transferred to a fresh jar and the original one kept, so that a record can be made of the larvæ that hatch. The number of larvæ that hatch is taken as an index of the number of eggs deposited, since it is impracticable to remove the eggs from the earth to make an accurate count, as they are easily

injured in handling. Records of the time spent in the different larval stages or the amount of food consumed may be secured by feeding the newly hatched larvæ in individual jelly glasses, as has already been described. When the larvæ become nearly full-grown they should be transferred to a larger jar, and it is better to place them in a wire cage sunk in the ground, so that they may have an opportunity to pupate in the soil without being disturbed.

These methods of rearing beetles were followed out, and in the spring and summer of 1908 and 1909 nearly 15,000 larvæ were reared and colonized in the field. Since that time it has been possible to collect both beetles and larvæ in the field, and the laboratory rearings for colonization have been discontinued.

LIFE HISTORY OF CALOSOMA SYCOPHANTA.

Contrary to general belief, the adults of this species live two or three years and sometimes four. This information has been secured by careful study of the habits of the insect carried out over a long period.

THE EGG (PL. I).

The egg is about 5.2 mm. long and 2.4 mm. wide, elliptical, tapering somewhat toward one end. It is white, with a faint yellowish tinge. The eggs are deposited in the ground by the females and hatch in from 3 to 10 days, depending upon the temperature. Careful experiments show that the time spent in the egg stage averages about 5.2 days in June and 4.4 days in July. Experiments have been tried to see whether or not hatching could be retarded by placing eggs in cold storage. In cases where they were exposed to freezing temperatures they shriveled and no hatching resulted.

THE LARVA (PL. I).

The larvæ on hatching are nearly white. They remain in the cavity occupied by the egg and gradually grow darker until they become jet black. They then make their way to the surface of the ground and begin searching for food. They attack caterpillars or pupæ with little regard to the size, cut through the body wall of their prey with their sharp mandibles, and feed on the liquids and soft tissues within. They molt twice before becoming full grown. These larvæ climb trees that are provided with rough bark and search for caterpillars or pupæ concealed in crevices. Molting frequently takes place on the tree trunk, so that the cast skins of the larvæ are frequently found on trees where they have been feeding. The full-grown larvæ average about 25.8 mm. in length and 5.7 mm. in width. The body is shining black, while the mandibles, legs, mouthparts, antennæ, and lateral and ventral abdominal markings are

dark brown; the dorsum of the last abdominal segment is chestnut-brown. The two caudal appendages forming a part of the last abdominal segment are short and quite erect, and are provided with a large, stout, dorsal tooth and a smaller lateral tooth, both of which bear spines. Length of time in the larval stage varies with the temperature and food supply. The following record of 12 larvæ which hatched June 20, 1908, shows the time spent in active feeding:

	Days.
First larval stage	2
Second larval stage	3
Third larval stage	9
Total	14

The weather during this period was warm and the food supply was ample. The time when larvæ are found in the field is governed largely by weather conditions in the spring, but ranges from June 25 to the middle of August.

DISTANCE TRAVELED BY LARVÆ.

As has already been stated, the larvæ of the species are capable of climbing trees, and this makes it possible for them to feed on caterpillars or pupæ that may be present on the trunks or large branches. In some cases molted skins of the larvæ have been found in large trees at a height of 50 feet above the ground.

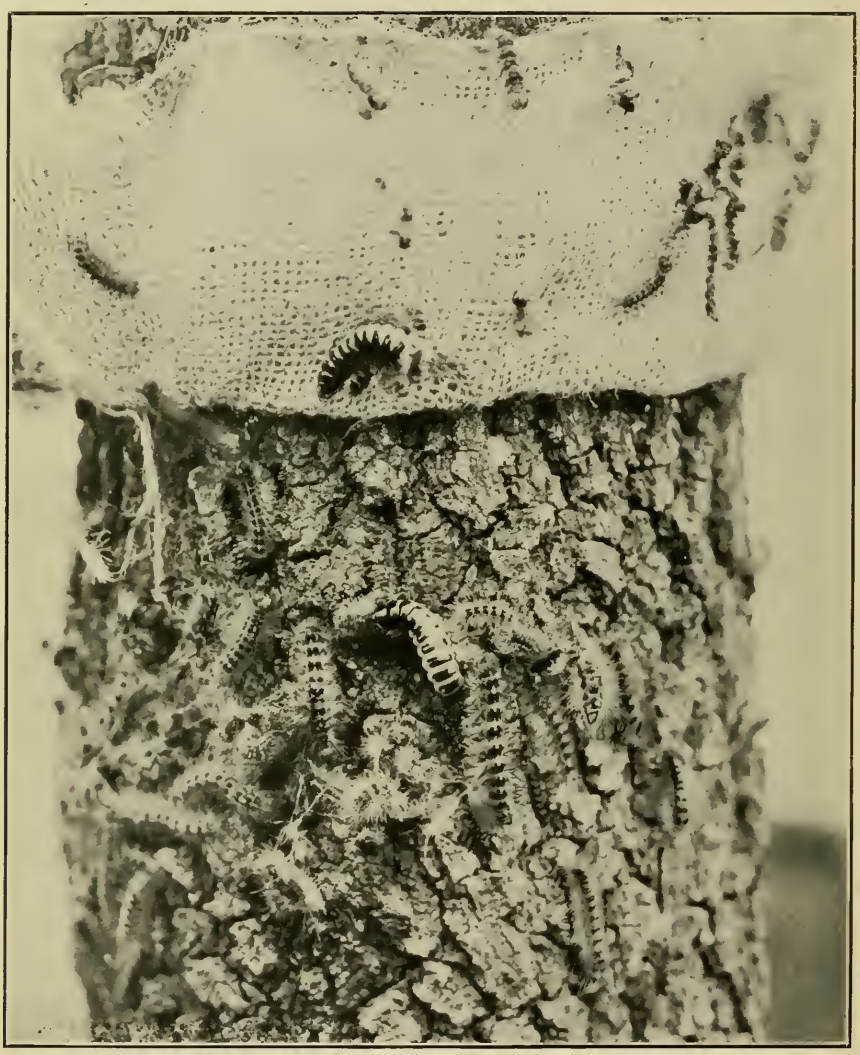
An experiment was carried on in 1910 to determine the distance that a newly hatched larva would travel if no food was supplied. The experiment started at 8.30 a. m., July 13, and continued uninterruptedly for 72 hours. Apparatus was constructed to measure accurately the distance traveled by this individual, which totaled 9,058 feet, or 1.78 miles. The weather was very hot during the time the experiment was carried on, and neither moisture nor food was supplied.

FEEDING HABITS OF LARVÆ.

The larvæ feed both by day and by night, and are more active when the weather is hot. As a rule, caterpillars are attacked from the side or from beneath, and if the specimens are hairy the favored place seems to be between the segments, where the larvæ can more readily pierce the integument with their sharp mandibles. Newly hatched *sycophanta* larvæ are able successfully to combat practically all caterpillars, regardless of size. Many specimens are injured to such an extent that they evidently die, and thus more caterpillars are prevented from transforming than are actually eaten. The pupæ of lepidopterons, especially those that are not provided with a cocoon, are particularly susceptible to attack by the Calosoma larvæ.

PUPÆ OF THE GIPSY MOTH THAT HAVE BEEN DESTROYED BY THE LARVÆ OF CALOSOMA SYCOPHANTA.

Note the irregular holes, which are characteristic. (From Burgess.)



LARVÆ OF CALOSOMA SYCOPHANTA FEEDING ON GIPSY MOTH CATERPILLARS UNDER BURLAP.

Photograph taken at Pine Bank Park, Malden, Mass., 1910. (From Burgess.)

The larvæ usually cut a hole between the segments of the pupæ (Pl. V), and after feeding begins the hole is gradually enlarged until the front portion of the body finds entrance to the pupa. The internal contents in most cases is completely devoured before the larva leaves the pupa to search for other food. The holes are always irregular in outline and can be easily distinguished from the exit holes of parasites. Gipsy-moth pupæ massed on the trunks of trees, underneath branches, or below burlap bands (Pl. VI) are favored locations as feeding grounds for Calosoma larvæ. In many towns in the infested gipsy-moth district one or more Calosoma larvæ can usually be found in each mass of gipsy-moth pupæ examined. These predaceous larvæ occasionally attack female moths, and several cases have been noted where the latter have been killed before they had an opportunity to deposit eggs.

Sycophanta larvæ feed freely on any lepidopterous larvæ or pupæ which they may find. A considerable number of cases have been noted where the larvæ have cut through the cocoons of the American tent caterpillar (*Malacosoma americana* Fab.) and forest tent caterpillar (*Malacosoma disstria* Hübw.) and have destroyed the pupæ within.

The life history of the Calosoma beetle is well adapted to that of the gipsy moth. The beetles are present and active during the time of year when gipsy-moth caterpillars are abundant and the larvæ are active and feeding while the gipsy moth is still in the pupal stage. No other common lepidopterous species which occurs in New England is so well adapted as a host of this beetle as the gipsy moth, and although large numbers of other caterpillars and pupæ are destroyed annually, the increase of the beetle is not as satisfactory in regions where the gipsy moth is not available for food.

In the summer of 1908 several series of experiments were conducted to determine the number of sixth-stage gipsy-moth caterpillars destroyed by the larvæ of *C. sycophanta*. It was found that on the average a single larva of this beetle would kill 41 full-grown caterpillars between the time of hatching and pupation. If smaller larvæ were attacked, a greater number would, of course, be destroyed. It is safe to say that 50 or more caterpillars would be necessary to satisfy the appetite of a Calosoma larva under field conditions. Most of the *sycophanta* larvæ hatch at a time when more gipsy-moth pupæ than caterpillars are available for food. Experiments show that on the average about 13 female pupæ are destroyed by each larva when fed in captivity. Observations in the field and jar experiments both indicate that a greater percentage of females than males is destroyed by the Calosoma larvæ, the average ratio being 75 per cent females to 50 per cent males.

EFFECT OF "WILT" ON CALOSOMA LARVÆ.

In the area infested by the gipsy moth a disease known as "wilt" is quite prevalent among caterpillars. A number of experiments have been conducted to determine whether *sycophanta* larvæ, if they were obliged to feed on caterpillars affected by this disease, would contract it and die. The experiments were conducted in 1910 and *sycophanta* larvæ were fed on diseased caterpillars in breeding jars. The results showed that the larvæ of this beetle suffer little if any from wilt. A few died, but no greater number than was the case in check experiments where healthy food was supplied. Only a single case has been noted in the field where Calosoma larvæ had apparently died from wilt, and as the specimens were not examined microscopically, death may not have been due to this cause. Beetle larvæ are so commonly found in masses of gipsy-moth pupæ and caterpillars which are dead or dying from wilt that if the beetle larvæ were susceptible to it, large numbers of dead specimens would be found.

EFFECT OF SPRAYING ON CALOSOMA LARVÆ.

The question has been repeatedly asked whether or not the spraying of infested areas would result in destroying the beetles or their larvæ on account of the belief that many of them would feed on poisoned caterpillars. Laboratory experiments, where caterpillars were taken from sprayed trees and used as food for beetle larvæ, show that the death rate was no greater than normal, while observations in the field have failed to reveal any case where the beetles or larvæ fed upon dead caterpillars or those in a dying condition from feeding on poisoned foliage. Apparently the beetles migrate in the field to locations where food is abundant. If eggs have been deposited in sprayed areas so that larvæ are abundant, little doubt remains that some of them may fail to secure food and die from starvation. No direct evidence is available to indicate that either the beetle or the larva is killed as a result of spraying, and we have always recommended that spraying should not be discontinued in cases of gross infestation in order to protect the beetles. The enormous increase of Calosoma seems to indicate that a discontinuance of spraying is not necessary.

STARVATION EXPERIMENTS WITH CALOSOMA LARVÆ.

Inasmuch as the ability of Calosoma larvæ to develop depends upon whether sufficient food can be found, a series of experiments was carried on in 1908 to determine how long they would survive in the different stages if no food was supplied. The larvæ were placed in jars containing a small amount of earth and no food was furnished.

The results showed that first-stage larvæ would live 3.56 days, second stage 6 to 9 days, and third stage 8 to 16 days before dying from starvation. This information, together with data secured on the distance which first-stage larvæ can crawl, indicates that the species is able to withstand adverse conditions and still survive.

PUPATION OF CALOSOMA LARVÆ.

Several attempts have been made to induce the larvæ to hibernate during the winter. A number of lots were placed in cold storage and several other experiments were conducted by placing the larvæ in jars of earth in a cold cellar. In every case, however, either the larvæ had transformed to pupæ, which had died, or to adults, when the jars were examined in the spring. After becoming full grown the larvæ entered the ground, formed a chamber, and entered the pupal stage. The depth to which the larvæ descend depends upon the condition of the soil. Occasionally pupæ of this beetle are found beneath boards or rocks, but in many cases they descend from 6 to 10 inches in loose soil before making the pupal chamber. In any event, pupation takes place above the frost line. After burrowing into the ground and forming a pupal chamber the body of the larva shortens, and after resting it transforms to pupa. The period from the time the larva stops feeding until pupation occurs averages about 10 days.

THE PUPA (PL. I).

The pupa of *Calosoma sycophanta* is pale yellow, about 25 mm. long and 12 mm. in width at the first abdominal segment. The mouthparts, antennæ, wings, and legs are folded beneath the head, the hind legs extending to the tip of the abdomen and the wings extending beyond the fourth abdominal segment.

Many experiments have been conducted in removing pupæ of this species from the cavities in which they pupated, but in most cases it is impossible to do this without causing injury and preventing normal emergence of the adult. In rearing this beetle care should be taken not to disturb the larva after it begins to form its pupal chamber, otherwise either a poor emergence of beetles or a considerable number of crippled specimens is likely to result. If definite records are desired regarding individual specimens, the larvæ should be allowed to pupate in wire cages in the ground. In case it is desired to rear through a large number of specimens without reference to definite records, a large number of larvæ can be placed periodically in one of the box cages previously mentioned. The time spent in the pupal stage averages about 13 days, and after the adults emerge they remain in the cavity which held the pupæ throughout the winter and do not ordinarily come to the surface of the ground until June 1

of the following spring. Many experiments have been tried in an attempt to force early emergence and with an idea of breeding this species during the winter in the laboratory, in order to increase the supply for liberation in the field. Efforts along this line have been futile. The species seems to have a well-fixed habit of winter hibernation, and apparently requires a long resting period. It is difficult to secure proper food for beetles that may be taken from hiberation during the winter, but, even if this could be obtained, no satisfactory way has been found to increase the number of broods annually.

THE ADULT OR BEETLE.

As has been previously stated, the beetles emerge about the first of June. The exact time varies slightly from year to year, depending upon the weather conditions. Beetle larvæ that transformed to pupæ and remained as beetles in the pupal cavities during the winter emerge at this time as well as other beetles that developed from larvæ in previous years. In July after the adults have finished feeding they burrow into the ground and form a cavity in which they remain the next winter. The distance beneath the surface varies greatly and depends to some extent on the looseness of the soil which they enter. They seldom go below the frost line, and, this being the case, the earth around them is usually frozen solid during the winter. The males and females enter hibernation about the same time, but the former usually emerge a day or two earlier in the spring. A few cases are on record where beetles have remained dormant in the ground continuously for nearly two years. In one instance a pair of beetles entered hibernation on July 28, 1910, and did not emerge from the ground until June, 1912. Several cases of this sort have been found as a result of careful notes from breeding experiments kept at the laboratory. In every case where this has occurred the beetles concerned were more than a year old. In no case have beetles failed to emerge the spring following their development from the larvæ. In connection with the hibernation of this species, it should be said that the beetles habitually live in that stage more than one year. As a rule they live for two years and several records indicate that it is not uncommon for them to remain in the beetle stage for three years. A record of one experiment shows that several females lived more than four years. Records kept at the laboratory indicate that the percentage of mortality during hibernation is rather high. It should be remembered that these beetles were placed in hibernating cages in the laboratory yard, and although here natural conditions are approximated as nearly as is possible, the location was not quite as suitable as if the insects had had an opportunity to make their own selection. In our experiments

the mortality of beetles during the winter runs from 22 to 35 per cent, first-year beetles showing the lowest death rate.

A large number of experiments were carried on in the spring of 1908 to determine whether it would be possible to induce this species to develop more than one brood in a single year. Beetles were removed from hibernation on March 4 and were fed in jars at the laboratory. Difficulty was experienced in securing a sufficient food supply, but the beetles did not feed at all freely and were rather inactive in the jars. Eggs were deposited a little earlier in the season than was the case when the species emerged normally, but the larvæ grew very slowly and did not develop much earlier than those which resulted from beetles that emerged early in June. The experiment indicated very conclusively that it was not possible to force this species and that the habit of developing a single generation a year is firmly fixed.

FEEDING HABITS OF ADULTS.

The beetles climb trees readily and travel out on the branches and sometimes cling to the leaves while searching for caterpillars. If disturbed they usually fall to the ground and immediately seek shelter underneath leaves or rubbish. The beetles usually seize the caterpillars in the middle of the back and cut through the body wall with their sharp mandibles. They feed upon the liquids and fatty material which form the body content of the caterpillar and usually injure many more than they actually devour. The average length of time during which the beetles feed is from about June 1 to July 15. From records secured in 1910 the shortest period of feeding was 32 days and the longest 66 days, with an average of 50 days. These records were secured from beetles kept in captivity. It will be noted that the time when the beetles are feeding corresponds roughly with the time when the gipsy moth is in the larval stage. This makes this beetle particularly adapted for feeding on the gipsy moth, and a further advantage results from the fact that the larvæ of *Calosoma sycophanta* are most active during the time the gipsy moth is in the pupal stage. The food of the adults is very similar to that of the larvæ; both are frequently found in the field feeding upon larvæ and pupæ of native Lepidoptera.

It is difficult to determine the number of caterpillars which are destroyed by a single beetle. This can only be done by feeding the beetles in captivity; and under these conditions they evidently do not destroy as many caterpillars as they would if they were living in the open. Experiments which have been conducted, using full-grown tent caterpillars and gipsy-moth caterpillars, showed that the average number of caterpillars destroyed by an old beetle was 328 and by young beetles 239. The young beetles—that is, those that are feeding

for the first year—do not eat nearly as many caterpillars as beetles that are older. On the other hand, the younger beetles seldom deposit eggs, while the older ones are very prolific.

Experiments conducted with small brown-tail moth caterpillars indicate that a much larger number of this species was destroyed. This is undoubtedly due to the small size of the caterpillars, and similar results would probably be secured if small gipsy-moth caterpillars were used for food.

In some of the laboratory experiments beef was offered to the beetles for food. They fed upon it to some extent for a short time, but after a week they refused to eat. Apparently they do not care for this substance if caterpillars are available.

EXPERIMENTS IN FEEDING BEETLES ON CATERPILLARS INFECTED BY WILT.

Several experiments have been conducted in feeding *sycophanta* beetles upon gipsy-moth caterpillars infected with the bacterial disease known as "wilt." Experiments were started in July, 1907, a single pair of beetles being fed from July 23 to August 14 with caterpillars which showed pronounced symptoms of the disease. Twenty-one larvæ were eaten, three were so badly injured that they died, and the remaining larvæ supplied to the beetles in the jar died from disease. These beetles ate slightly less than another pair that were fed on healthy caterpillars. Both pairs entered hibernation and those that were furnished diseased caterpillars showed no ill effects. Several similar experiments have been conducted since that time, and the results indicate that these beetles are not susceptible to the "wilt." Each year large numbers of gipsy-moth caterpillars die from the disease in jars where Calosoma beetles are confined for experiments, and if it was seriously destructive to the beetles or their larvæ the fact would have been determined by heavy mortality among them.

EFFECT OF SPRAYING ON BEETLES.

Several attempts have been made to determine whether Calosoma beetles are injured or killed by feeding on gipsy-moth caterpillars taken from sprayed trees. In 1910 a small area of brush growth near the laboratory was sprayed with arsenate of lead, and gipsy-moth caterpillars collected from time to time were furnished the beetles for food. Check experiments were also run in unsprayed areas. The experiment failed to show that any of the beetles were injured by feeding on caterpillars taken from sprayed foliage. Several colonies of beetles have been liberated in woodland that has been heavily sprayed, and not infrequently beetles are found on street or park trees which have been sprayed with arsenate of lead. Dead beetles or their larvæ are found very rarely, and thus it is evident

that no wholesale injury to the species is caused by their feeding on poisoned caterpillars.

STARVATION EXPERIMENTS.

In 1910 experiments were conducted to determine the length of time that these beetles could survive without food. For this purpose two pairs of young beetles and two pairs of old beetles were placed in jars of earth in one of the cages in the laboratory yard. The results of the experiment are shown in Table II:

TABLE II.—*Starvation experiment to determine the length of time adult Calosoma sycophanta can live without food.*

Calosoma sycophanta.	Date emerged from hibernation.	Date male died.	Length of time male lived without food.	Date female died.	Length of time female lived without food.
	1910.	1910.		1910.	
Young pair	May 26	June 26	1 month	July 9	1 month 13 days.
Do	...do	June 29	1 month 3 days	July 5	1 month 9 days.
Old pair	...do	July 17	1 month 21 days	June 26	1 month.
Do	...do	June 30	1 month 4 days	(1)	1 month 21 days.[1]

[1] This female, after living without food for 1 month and 21 days, was offered several full-grown gipsy-moth caterpillars July 17 and ate two in 10 minutes. The next day a male was added and copulation was attempted several times, but without satisfactory results. The female died July 30 without depositing eggs. During the 12 days the pair were in the jar 33 sixth-stage gipsy-moth caterpillars were eaten.

This experiment shows that beetles of this species can live during the summer for a month or more without food. Old beetles appear to withstand starvation better than young beetles, and males die sooner than females. In 1907 a field colony of beetles was liberated in order to test their ability to survive where the food supply was very limited. Fifty specimens, 25 of each sex, were liberated in woodland at Peabody, Mass., August 28. The beetles were received from Europe early in the month and had been supplied with very little food after their arrival. At the time they were liberated there were no gipsy-moth caterpillars in the field and very few pupæ. An occasional native caterpillar could be found, but they were rare in the vicinity of the colony. Several examinations were made the following spring and summer. On July 8 Calosoma larvæ were found, showing that the species had survived and that reproduction had taken place. This indicates that the beetles are able to survive under very unfavorable conditions.

In order to determine how far male beetles might be attracted by females, several experiments were conducted, but negative results were secured.

REPRODUCTION.

After emerging from hibernation and feeding for a few days, copulation takes place and eggs are deposited by the females. It is neces-

sary for the latter to mate several times during the season, or a large percentage of infertile eggs will be laid. Old beetles lay many more eggs than young beetles. The highest number of eggs laid by a single female in a season was 653. If an average is taken covering all the beetles under observation for a single year, both young and old, the rate of increase—that is, the average number of eggs deposited by each female—will be about 100. The result of several years' work in rearing beetles in confinement indicates that it is a common habit of this species to oviposit sparingly, if at all, the first summer, and to lay eggs freely the second season. If conditions are favorable the first year, a number of eggs may be laid, while if they are unfavorable oviposition is postponed until the second or third summer, as the case may be. It sometimes happens that eggs are laid the first and third summers, but not during the second; at any rate, each female will lay about an equal number of eggs, but the time they are deposited varies greatly.

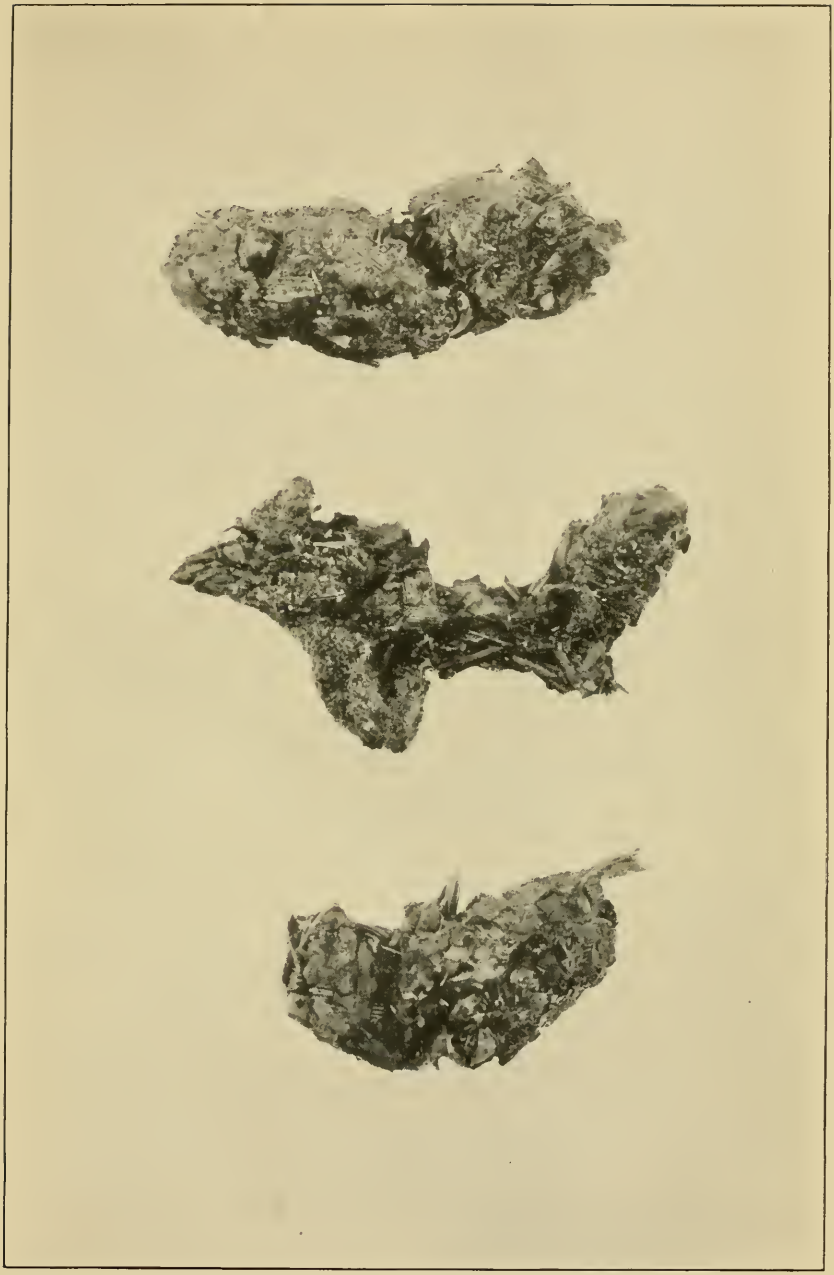
.The data secured from field colonies indicates that the same conditions apply. Two-thirds of the localities that were colonized with beetle larvæ have shown some reproduction the year following planting, while colonies where adults were liberated usually show much larger increase. The jar records indicate that the old beetles multiply seven times as fast as the young ones, and in the field, based on the number of molt skins found in several colonies, the average is 10 to 1 in favor of the old beetles.

HABITS OF FLIGHT.

For a number of years it was believed that these beetles did not fly. They were frequently seen in trees, and when disturbed would fall to the ground without making any effort to use their wings. A number of observations, however, prove that the species flies quite freely, particularly early in the spring. There is at that time considerable migration of the adults after they emerge from hibernation, and they undoubtedly seek localities where food is plentiful. The fact that beetles have been found more than 20 miles outside the area where they were colonized indicates that spread is accomplished by flying or that the species was carried on vehicles or in some other way.

ATTRACTION OF ADULTS TO LIGHT.

Several native species of Calosoma are attracted to strong light. Although many observations have been made in eastern Massachusetts, where *sycophanta* was first colonized, and where the species is abundant, it has never been taken at arc lights, and we have received no record to that effect from various collectors in this vicinity. Several specimens are reported to have been taken at electric lights



EXCREMENT OF SKUNK COLLECTED IN THE FIELD, SHOWING MANY FRAGMENTS OF ADULTS OF CALOSOMA SYCOPHANTA. (ORIGINAL.)

at Salisbury Beach, Salisbury, Mass., in 1913. It is probable that the species is occasionally attracted to lights, but it is apparent that this beetle does not frequent lights as commonly as other species of the same genus.

EXPERIMENTS IN DROWNING BEETLES.

Early in the spring of 1910 a number of experiments were conducted to determine whether beetles could continue to live after being submerged in water for any length of time. This information was quite desirable, inasmuch as areas where the beetles hibernate during the winter might in the spring be covered with water for a considerable period, so that unless the species are able to withstand submergence many specimens might be destroyed in this way.

March 17, 1910, cages containing frozen earth were dug up and two male beetles were removed from their cavities and put in a jar of water. At 11 a. m. the jar was placed in the laboratory ice chest and kept at a temperature of 39° F. Some pieces of cloth and two small blocks of wood were put in the jar with the intention of keeping the beetles submerged, but at 5.58 p. m., when an examination was made, both beetles were found swimming about in the water. They were again submerged by placing a quantity of blotting paper inside of the jar, but on the following morning they had succeeded in making their way to the surface. A wooden float was then constructed which was placed in the jar in such a manner as to keep the insects under water. They were kept in this position four days, although every 12 hours they were taken out and examined to see if they showed signs of life. At the end of this period they were removed, apparently dead, but in less than an hour they revived sufficiently to begin feeding on cutworms.

This experiment shows that beetles of this species can live for at least four days, and probably longer, if submerged in water a few degrees above the freezing point.

March 17, 1910, several small wire cages, used for feeding larvæ, each of which contained a newly formed beetle, were dug up and submerged in a tub of water to see if the insects would survive this treatment. There were several inches of frost on the top of each cage and the temperature of the water was about 39° F. March 18, at 8 a. m., one female had emerged and was clinging to the wire just above the water. An examination of the earth in this cage showed that the hibernation cavity was about 6 inches deep, and as soon as it thawed out the insect made its way to the surface of the water.

Another cage was examined after it had been submerged 24 hours and a living beetle was found 3½ inches below the surface of the earth. The cage was replaced and removed later in the day and it was found that the beetle had worked its way to a point a half inch

below the surface of the earth. It appeared dead, but on removal soon revived.

At the end of 48 hours another cage was examined, and a live beetle found 3½ inches below the surface of the earth. This cage was replaced and on the following morning, after it had been submerged for 2½ days, the beetle was found on the surface of the water.

The last cage was opened at the end of four days, and an active female was found in the earth, which was now very compact. The beetle was replaced in the mud and the cage submerged, but at 3.10 p. m. it came to the surface of the water, after having remained beneath it four days and two hours.

These experiments indicate that this species is able to withstand excessive amounts of moisture and that in the spring, when lowlands are flooded, the majority of the insects will survive, apparently without serious inconvenience.

On March 21 a female Calosoma beetle that had been submerged for four days and two hours was placed in a tub of water and floated about on the surface. It seemed desirable to ascertain how long the insect would remain alive and float when the temperature of the water was maintained at about 39° F., and also whether it was able to make any progress in swimming. During the first hour and fifteen minutes the insect swam a distance of 22 inches. It rested on the water very easily, less than one-half of the body being submerged. The legs moved continually, but its progress was very slow. This beetle remained in the tub of water 15 days and at the end of that period was removed for dead. In a few hours it revived and began feeding, and was used later in the summer in rearing experiments. This shows that in the spring beetles of this species might survive several days if they should fall into ponds, and that they would probably float with the current and might be distributed quite a long distance in this way, especially if they fell into streams or rivers.

NATURAL ENEMIES.

It is undoubtedly true that this species is eaten to some extent by birds, and the hairy woodpecker has been charged with destroying it on several occasions. The crow has been observed to feed on the beetles and also to carry them to their nests which were occupied by young birds. Among the other vertebrate enemies may be mentioned skunks, raccoons, and foxes. The last two mentioned, when kept in captivity, will feed on these beetles very freely. Abundant evidence has been secured that skunks destroy large numbers of the beetles. In some sections where these insects were very abundant it was found that the remains of the beetles formed the chief constituent of the excrement of this animal. (Pl. VII.) Not only do the skunks secure beetles which may be on the ground, but they

undoubtedly obtain many that have just transformed to the beetle stage and are just beneath the surface. In several places, where beetles were numerous and were doing good work in destroying gipsy-moth caterpillars, it was found later in the season that the ground beneath the trees had been uprooted to a considerable extent and skunk droppings containing large numbers of beetle remains were abundant in the locality.

These beetles are also attacked by a tachinid fly, probably *Viviania georgiae*, as a few specimens of this species have been reared from beetles which died after they had been brought in from the field.

Under laboratory conditions the beetles and their larvæ are sometimes seriously attacked by a mite known as *Tyroglyphus armipes* Bks. It is improbable that they suffer from this enemy under field conditions, but unless breeding jars are kept free from dead caterpillars, considerable difficulty is likely to result in rearing the insect in confinement.

COLONIZATION OF CALOSOMA SYCOPHANTA.

Colonies of this species were first liberated in the field in 1906 in the towns of Saugus, Malden, Winchester, Burlington, and Lynnfield, Mass. Other colonies have been released since that time in territory where the insect did not occur and where gipsy-moth infestation was severe. There have been liberated in the field about 2,700 beetles which were imported from Europe; in addition to this, during the first two or three years following 1907, colonies of larvæ and some beetles reared at the laboratory were also released in the field. Since 1910 this species has not been received from Europe, and most of the specimens colonized have been collected in eastern Massachusetts, where the beetles have become abundant. Table III gives a summary of the number of beetles imported, as well as those collected and colonized since the work began.

TABLE III.—*Number of living Calosoma sycophanta imported, and number of beetles and larvæ colonized.*

Year.	Received.	Colonized from importations.	Colonized from rearings and field collections.	
			Adults.	Larvæ.
1906	693	389	.....	.....
1907	967	578	.....	.....
1908	675	430	.....	2,300
1909	405	250	.....	6,100
1910	1,305	1,064	452	6,380
1911	.....	.....	621	1,104
1912	.....	.....	176	.....
1913	.....	.....	3,014	2,901
1914	.....	.....	4,244	330
Total	4,045	2,711	8,507	19,115

In addition to the beetles colonized, as given in Table III, 340 living specimens were shipped from the laboratory during 1912 and 1913. Most of these went to New Brunswick, Canada, where an infestation of the brown-tail moth exists, but a small lot was shipped to the commissioner of horticulture of California for colonization in that State, and another lot was forwarded to New Mexico, where a serious outbreak of the range caterpillar (*Hemileuca oliviae* Ckll.) exists.

In 1914, 1,830 specimens were collected by Mr. L. S. McLaine, an assistant of Dr. C. Gordon Hewitt, entomologist to the Dominion of Canada, and shipped to New Brunswick, and 1,700 were obtained by Mr. H. E. Smith and forwarded to New Mexico by arrangement with Prof. F. M. Webster, in charge of cereal and forage insect investigations in the Bureau of Entomology.[1]

METHODS OF SECURING DATA FROM FIELD COLONIES.

In order to determine whether this species has increased in spread under natural conditions, a large amount of work has been carried on each year in the field. Owing to the large size of the beetle and its larvæ, it is comparatively easy to make observations on this species. For the first few years after liberations were made observations were carried on in the localities where the colonies were planted. The work was taken up about the 1st of July and continued as long as information could be secured in August. Effort was made to determine not only whether the species had survived, but to find out whether it was spreading. This work gave very gratifying results. On trees which were burlapped it was possible in many cases to find the beetles or their larvæ feeding on gipsy-moth larvæ or pupæ beneath the bands. The beetle larvæ feed extensively on gipsy-moth pupæ, and it is quite easy to determine if pupæ have been destroyed by this means, even though the insect may not be present. As the larvæ of *sycophanta* climb trees and feed among masses of pupæ, an examination of these masses in midsummer usually indicates whether the species is present. An additional help in this respect results from the fact that these beetle larvæ molt among the masses of pupæ on the trees, and unless there are heavy rains, which wash these molted skins to the ground, it is possible, for a period of several weeks after actual feeding took place, to determine whether the species has been present. Using this information as a guide, parties of men have been employed each year to examine infested places in the towns outside of localities in which colonization actually took place. In this way it has been possible to determine the spread of the insect from year to year

[1] Results of the introduction into New Mexico will be set forth in detail in a report on the range caterpillar investigation of this bureau.

Bul 231, U.S. Dept of Agriculture

MAP

showing

DISPERSION OF THE CALOSOMA BEETLE

and

GIPSY MOTH IN NEW ENGLAND — 1914.

— 1911 - DISPERSION of C. SYCOPHANTA.
— 1912 - " " "
— 1913 - " " "
— 1914 - " " "

• - COLONIES LIBERATED-1914. x - RECOVERIES MADE - 1914.

▬ = GIPSY MOTH QUARANTINE LINE - 1914.

and to secure data on the abundance of the species and the effectiveness of its work.

The accompanying map (Pl. VIII) shows the territory infested with the gipsy moth in 1914; also the areas where the Calosoma beetle was found from the years 1910 to 1914, inclusive.

DISPERSION OF CALOSOMA SYCOPHANTA.

Table IV shows the annual dispersion of *Calosoma sycophanta* since it was introduced into Massachusetts. This information has been secured by careful field examinations, and towns have not been included in the area unless the beetles or their larvæ have been found in several localities throughout the town.

TABLE IV.—*Table showing annual dispersion of Calosoma sycophanta in New England, 1909–1914.*

Year.	Area.	Year.	Area.
	Sq. m.		*Sq. m.*
1909	9	1912	1,615
1910	106	1913	3,003
1911	425	1914	5,445

The statements which follow give a list of the towns and cities in Massachusetts, New Hampshire, Maine, Rhode Island, and Connecticut in which colonies of this species have been liberated, the number released, and the places where they have been found as a result of spread from nearby towns. The records are complete up to and including 1914, and the information is given somewhat in detail, so that it may be of value to owners of property or residents in the sections concerned.

MASSACHUSETTS.

Abington.—No colonies were liberated in this town. Examinations of woodlands in 1914 resulted in finding traces of the beetles, although little damage was noted by the gipsy moth.

Acton.—In 1910 a colony of 200 larvæ was liberated in the western part of the town. During August, 1912, the larval molt skins were found in many woodlands throughout, and further evidences of the increase and efficiency of the species were reported in 1913 and 1914.

Amesbury.—In 1910 a colony of 200 larvæ was liberated in woodland off Haverhill Street. August, 1912, examinations showed them to be present in many localities throughout the town, and in 1913 and 1914 further reports indicated that they had become numerous in these sections.

Andover.—During 1910, 100 beetles were liberated in this town. In 1911 they were recovered in a few localities. They were recovered in 26 different localities in 1912. Additional data secured in 1913 and 1914 showed them to be present in large numbers throughout. These records are indicative that these beetles are common enough throughout this section to be accomplishing an appreciable amount of good as an enemy of the gipsy moth.

Arlington.—In 1910, 200 beetle larvæ were colonized. During 1911 they were recovered in various localities. No further examinations have been made, as the results indicated that this species was well established here.

Ashburnham.—In 1914, 87 beetles were colonized in a section where there was a heavy infestation of gipsy moths. Later reports show that the beetles had spread sparingly into other sections.

Ashby.—During 1914, 174 beetles were liberated in two localities where gipsy moths were abundant. They also made their appearance in other sections as a result of spread from other towns.

Ashland.—A colony of 100 beetles were liberated in 1913 at a locality where the gipsy-moth infestation was moderate. Later in the season this species was recovered at points distant from the colony. In 1914 it was universal throughout the town.

Avon.—No colonies were liberated here, but in 1913 recoveries were made in the southern part of the town, and a satisfactory increase was noted in 1914.

Ayer.—In 1913 beetles were recovered in three localities, although no colonies had been liberated. This species showed remarkable increase in 1914.

Barnstable.—No beetles were liberated in this town. In 1914 this species was reported as abundant in various localities.

Barre.—No colonies were liberated, but beetles were reported in 1914, which is a result of spread from other towns.

Bedford.—During 1910, 100 beetles were liberated. In 1911 this species was recovered in localities surrounding the colony. Examination made in 1912 showed them to be present in 10 widely separated points throughout the town. In 1913 and 1914 the beetles were common in all sections.

Belmont.—During 1911 larval molt skins were found in a number of localities, although no liberations were made here. In 1912, 1913, and 1914 beetles were present in all the infested localities.

Berlin.—No colonies were liberated here, but in 1913 beetles were found in two localities. Reports in 1914 show this species to be quite abundant.

Beverly.—During 1909, 200 beetle larvæ were liberated off Essex Street. In 1910 beetles were recovered in points surrounding the colony. This species was found in many localities in 1911, and in 1912, 1913, and 1914 it had become well established.

Billerica.—In 1909, 100 beetles were liberated. Examinations in 1912 showed them to be present in most of the woodland areas. This species was very common in 1913 and 1914.

Bolton.—Although no colonies were liberated here, the beetles were found in three localities in 1913. Reports show this species to be abundant in 1914.

Boston.—During 1910, 200 beetle larvæ were liberated in the Hyde Park district. In 1911 they were recovered in the Jamaica Plain and West Roxbury sections. Inspections in 1912 showed them to be common in the Hyde Park, Jamaica Plain, and Dorchester sections; also in Franklin Park. They were reported very common and doing efficient work in woodlands where gipsy moths were present in 1913 and 1914.

Boxboro.—No colonies were liberated here. Larval molt skins were found in one locality in 1912. During 1913 this species was found in other parts of the town, and in 1914 it had become quite common.

Boxford.—In 1910, 200 beetle larvæ were liberated. During 1912 larval molt skins were found in 10 widely separated localities. Additional data secured in 1913 and 1914 showed them to be well established throughout the town.

Boylston.—Although no colonies were planted here, beetles were recovered in one locality in 1913. In 1914 this species was reported from many sections of the town.

Bradford.—In 1910, 200 beetle larvæ were liberated. During 1912 larval molt skins were found in one locality. Reports in 1913 and 1914 show them to be rather common throughout the town.

Braintree.—Two hundred beetle larvæ were liberated here in 1909. Examinations during 1910 showed them to be present at and near the colony. In 1912 beetles were found in three separated localities. They were reported quite common in 1913 and 1914.

Brockton.—No colonies were liberated here, but in 1913 beetles were found in the northern part of the city. Further notes in 1914 showed that the beetles had increased considerably.

Brookline.—During 1908, 145 beetles and 100 beetle larvæ were liberated. In 1909, 200 beetle larvæ were added to another infested woodland. Examinations in the summer of 1909 showed that the beetles had migrated somewhat. During 1910 they were reported as reproducing and spreading favorably. In 1911 they had spread into 20 different localities and since that time they have steadily increased and have become well established.

Burlington.—Forty beetles were liberated here in 1906. In 1907 and 1908 a few larval molt skins were found. During 1909 beetles were found three-fourths of a mile from the colony, and in 1910 they were noted a considerable distance from the center of the original colony. In 1911 and 1912 this species was reported common in all sections of the town. Later reports show them to have increased and become well established.

Canton.—During 1911, 100 beetles were liberated. In 1912 larval molt skins were found in the center of the colony and in five isolated localities of the town. Reports of 1913 and 1914 show this species to be present in large numbers and steadily increasing.

Carlisle.—In 1910, 100 beetles were liberated. A thorough inspection was made in 1912 and they were recovered in a number of different localities. Since that time they have steadily increased and become effective.

Carver.—During 1913, 85 beetles were liberated. In 1914 larval molt skins were found common in all parts of the town where gipsy moths were present.

Chelmsford.—One hundred beetles were liberated here in 1910 and during 1912 they were recovered in several localities. Reports made in 1913 and 1914 found them present in large numbers.

Clinton.—No beetles were liberated here, but examinations made in 1914 show them to be rather common in all parts of the town.

Cohasset.—In 1909, 400 beetle larvæ were released in this town. During 1912 they were recovered in several localities. Additional data secured in 1913 and 1914 show this species to be well established.

Concord.—Fifty beetles and 100 beetle larvæ were liberated here in 1908, and 400 larvæ in 1909. Examinations made in 1910 indicated that they had spread a considerable distance from where the colonies were liberated. In 1911 and 1912 this species was recovered in several sections and reports made in 1913 and 1914 show them to be abundant in all localities.

Danvers.—During 1909, 300 beetle larvæ were liberated, and in 1910 they were recovered a short distance from the colony. Examinations made in 1911 resulted in finding molt skins in numerous localities. Further evidence secured in 1913 and 1914 showed this species to be well established.

Dedham.—In 1910, 200 beetle larvæ and in 1911, 100 beetles were liberated. Beetles were present in most of the woodlands in 1912. In 1913 and 1914 they were found to have increased considerably and had become well established.

Dover.—Two hundred beetle larvæ were liberated here in 1910. In 1912 larval molt skins were found in five widely separated localities. Data received

in 1913 gave evidence that they were well established, and in 1914 they were found to be very abundant.

Dracut.—In 1910, 100 beetles were liberated. During 1912 they were recovered in various localities. In 1913 and 1914 the species was well established and very abundant in some localities.

Dunstable.—No colonies were liberated in this town, but in 1912 beetles were found in three widely separated sections. Reports of 1913 and 1914 show this species to be rather abundant in various localities.

Duxbury.—Beetles were found in the northern part of this town in 1913, although none had been liberated. In 1914 examinations showed them to be present in all sections.

Easton.—In 1913, 100 beetles were liberated and reports in 1914 showed the beetles to have spread to other localities.

East Bridgewater.—No beetles were liberated here, but in 1914 they were found in localities where gipsy moths were present in sufficient numbers.

Essex.—In 1909, 549 beetle larvæ were liberated in three separated localities. Beetles were recovered at and near these colonies in 1910. During 1912 examinations showed them to be present in large numbers in all sections, and in 1913 and 1914 they were reported to be abundant in all gipsy-moth infestations.

Fall River.—No liberations were made here, but in 1914 Mr. Norman S. Easton, President of the Society of Natural History, reported finding an adult in the center of the city.

Fitchburg.—One hundred beetles were liberated in 1913 in the western part of the city. During 1914, 87 beetles were liberated on Ashburnham Hill Road and 87 near Burbank Hospital. Later reports show them to be present in nearly all of the wooded sections of the city.

Foxboro.—In 1913, 100 beetles were liberated in this town, and during 1914 they were recovered in three different localities.

Framingham.—Two hundred beetle larvæ were liberated in 1910 in the northeastern part of the town. During 1912 they were recovered in several locations in the eastern part and in 1913 the species was quite common in the western section. Further data secured in 1914 showed them to be quite abundant in all localities.

Franklin.—No beetles were liberated, but in 1914 larval molt skins were found in some sections of the town.

Georgetown.—In 1909, 200 beetle larvæ were liberated in the southern part of the town. They were recovered in and near the colony in 1910. During 1912 examinations showed them to be present in a number of localities, and they were reported to be abundant in 1913 and 1914.

Gloucester.—In 1908, 275 beetle larvæ were liberated in three localities of the town. Examinations in 1910 showed them to be present in localities some distance from the original colonies, while in 1911 they were recovered in several sections. They were reported abundant in a number of localities in 1913 and 1914.

Grafton.—90 beetles were liberated in the northern part of the town in 1914. Later in the season they were recovered in the northern and eastern sections.

Groton.—No colonies were liberated here, but examinations made in 1913 and additional data secured in 1914 indicated that the beetles were well distributed in all sections of the town.

Groveland.—In 1910, 200 beetle larvæ were liberated in the center of the town, and in 1913 they were recovered in several well-separated localities. Later reports show this species to be abundant in all sections.

Halifax.—Although no colonies were released in this town, beetles were found in nearly every locality examined in 1914.

Hamilton.—During 1909, 104 beetles and 100 beetle larvæ were colonized in this town. In 1912 they were found in several localities visited. Reports in 1913 and 1914 proved that this species was well distributed and quite abundant in some districts.

Hanover.—No beetles were liberated here, but a careful survey of the woodlands made in 1913 resulted in finding them in no less than nine well-distributed localities. Later reports indicate their increase and further spread.

Hanson.—While no colonies were liberated here, examinations in 1913 and reports made in 1914 showed them to be common in a number of localities where gipsy moths were in sufficient numbers.

Harvard.—No beetles were liberated in this town, but examinations made in woodlands infested by gipsy moths in 1913 gave proof that this species was present in nearly all localities. In 1914 they were reported quite common throughout.

Haverhill.—In 1910, 200 beetle larvæ were liberated in the southeastern part of the city. During 1912 they were recovered in several localities in the wooded sections. Later reports prove that this species is quite common in the areas infested by gipsy moths.

Hingham.—Eighty-three beetles were liberated here in 1912. Later in the year they were recovered in five different localities. In 1913 and 1914 they had become well established.

Holbrook.—No liberations were made in this town, but recoveries have been made in all the surrounding towns near the town line.

Holden.—In 1913, 190 beetle larvæ were liberated, and in 1914, 90 beetles were colonized off Princeton Road.

Holliston.—During 1913, 100 beetles were liberated in the central part of the town. They were recovered in one locality outside of the colony later in the year. As a result of examinations in 1914 it was found that this species had little chance of increase, as the gipsy-moth infestations were light.

Hopkinton.—One hundred beetles were liberated here in 1910. During 1913 they were recovered in one locality. No larval molt skins were found in 1914, the gipsy-moth infestation being very light.

Hudson.—In 1910, 100 beetles were liberated on Priest's Hill. Examinations in 1912 showed them to be present in a number of locations. In 1913 and 1914 this species had become quite abundant throughout the town.

Ipswich.—During 1909, 200 beetle larvæ were liberated in the northern part of the town. Larval molt skins were recovered in large numbers in some localities during 1912. Reports received in 1913 and 1914 show that the species had increased and was well established.

Kingston.—In 1912, 93 beetles were liberated here. They were recovered in four near-by localities in 1913, and scouting in 1914 showed them to be present in all parts of the town.

Lakeville.—No colonies were liberated here, but larval molt skins were found in the center of the town in 1914.

Lancaster.—No liberations were made here, but in 1912 beetles were noticed in a few localities. Reports in 1914 show them to be quite common in a number of sections.

Lawrence.—Two hundred beetle larvæ were liberated in South Lawrence in 1910. In 1911 they were not recovered, except in adjoining towns near the city line. During 1913 and 1914 they were reported in large numbers in all the wooded sections.

Leicester.—Although no beetles have been liberated here, they were reported as being present in the southern part of the town in 1914.

Leominster.—In 1913, 200 beetle larvæ were liberated in the southeastern part of the town. From examinations made the same year they were found present in a few localities quite remote from the original colony, and in 1914 well distributed.

Lexington.—During 1908, 100 beetle larvæ were liberated off State Road, and in 1909, 200 larvæ were colonized in the eastern part of the town. A careful examination was made in all infested woodlands in 1912, and beetles were recovered in 40 different localities. Later reports prove that they are abundant and doing efficient work.

Lincoln.—In 1908, 100 beetle larvæ were liberated in the northwestern section. During 1910 they were recovered in localities somewhat remote from the colony. Examinations in 1911 and 1912 showed them to be present in all the localities infested by gipsy moths, and since that time their effective work has been very noticeable.

Littleton.—In 1910, 200 beetle larvæ were liberated a short distance from the railroad station. During 1912 examinations showed them to be quite common in some localities. Later they were reported abundant in most sections of the town.

Lowell.—During 1910, 200 beetle larvæ were liberated near the Lowell General Hospital. In 1912 they were recovered in five different localities. In 1913 and 1914 the species had increased and was doing efficient work in the woodland areas.

Lunenburg.—No colonies were liberated in this town, but in 1913 beetles were recovered in a few localities in the eastern part. During 1914 they had spread to all sections, and in one point near the center they had increased to such proportions that the adults and small larvæ destroyed about 49 per cent of the gipsy-moth caterpillars. As a result of counts made after the gipsy moths had reached the pupal stage it was found that about 78 per cent of the pupæ were destroyed by the beetle larvæ alone.

Lynn.—No colonies were liberated in this city, but colonies were planted in Lynnfield and Saugus near the Lynn Woods Reservation. In 1910 beetles were recovered in a number of localities in the reservation. Examinations in 1911 showed them to be well established in nearly all parts of this woodland. Since that year they have continued to increase and have assisted materially in lessening the damage done to these woodlands by the gipsy moths.

Lynnfield.—In 1906, 100 *C. sycophanta* and 20 *C. inquisitor* adults were liberated near Broadway. Later this same year 218 of the former species were colonized two miles distant. *C. sycophanta* was recovered in 1908 and 1909. From examinations in 1910 these beetles were found spread throughout the southern part of the town, and since that time they have increased in large numbers and are doing satisfactory work.

Malden.—During 1906, 40 beetles were liberated in the Maplewood section. They were recovered in a few localities in 1908 and 1909. This species from 1910 to 1914 was found to have spread to all sections and was doing very efficient work in destroying the gipsy moths.

Manchester.—In 1909, 73 beetles and 850 beetle larvæ were liberated in five localities of this town. Scouting in 1911 showed them to be present in and at a considerable distance from the colonies. In 1912 this species was found to be common in many of the woodland areas. During 1913 and 1914 they had become well established throughout.

Mansfield.—No beetles were liberated, but in 1914 larval molt skins were found in a few localities.

Marblehead.—In 1908, 200 beetle larvæ were liberated one-half mile east of Forest River station. They were recovered in small numbers in 1910. Examinations made in 1911 showed them to be present in and at some distance from the original colony. Later reports indicate that this species has increased to great numbers in some localities.

Marlboro.—No beetles were liberated in this town, but in 1912 larval molt skins were found in woodlands in the northeastern part. During 1913 they were found in the southern and western sections. Later reports show that this species is rather common in the wooded sections of the city.

Marshfield.—In 1910, 200 beetle larvæ were liberated near Marshfield Center. During 1913 several examinations were made, and larval molt skins were found in a number of widely separated localities. Later reports show them to be well established.

Mashpee.—Eighty-five beetles were liberated in 1913 in woodland north of Wakeby Pond and 316 beetle larvæ in woodland south of Johns Pond. As a result of scouting in 1914, it was found that this species had dispersed into most of the infested sections of the town.

Maynard.—In 1910, 200 beetle larvæ were liberated in badly infested woodland. Observations were made in 1912, and the species was recovered in and around the colony. In 1913 and 1914 the species had become well established throughout the town.

Medfield.—During 1910, 100 beetles were liberated in Rocky Woods. In 1912 larval molt skins were found in a few localities around the colony. As a result of further scouting in 1913 and 1914 it was found that they were rapidly spreading and increasing.

Medford.—No beetles were liberated here, but in 1910 indications of their presence were noted in the northern part of the city. Later reports show them to be common in all the woodland areas.

Medway.—In 1913, 100 beetles were liberated in Black Swamp. They were recovered in a few woodland areas in 1914.

Melrose.—During 1909, 200 beetle larvæ were liberated in woodland near the Saugus-Wakefield line. Beetles were found in small numbers throughout the entire area in 1910. This species at the present time is common and doing efficient work in all the woodland areas.

Merrimac.—Two hundred beetle larvæ were liberated north of Main Street, in Nichols Woods. Molt skins were secured in a few localities in 1912. In 1913 and 1914 they had become quite common in some sections.

Methuen.—During 1910, 200 beetle larvæ were liberated in the eastern part of the town near the Haverhill line. Their presence was noted in 20 or more localities in 1912, and a constant increase and spread has been reported since that time.

Middleboro.—In 1913, 85 beetles were liberated in woodland infested by the gipsy moth off Wareham Street This species was recovered in all parts of the town in 1914.

Middleton.—One hundred beetles were liberated in woodland off East Street in 1910, and in 1911 they were recovered in a number of localities. Further examinations in 1912 showed that the beetles were still increasing and had become well established in 1913 and 1914.

Milford.—No liberations were made in this town, but it was reported that beetles were seen in the northern part of the town, near the Hopkinton line, in 1914.

Millbury.—No beetles were liberated here, but scouting in 1914 showed them to be present in small numbers in some parts of the town.

Millis.—In 1913, 100 beetles were liberated in the northern part of the town, and in 1914, 95 adults were liberated in the eastern part. As a result of examinations in 1914, it was found that this species had spread rapidly and could be found in all sections of the town.

Milton-Quincy.—During 1909, 200 beetle larvæ were liberated near Shawmut Spring, in Cunningham Park. In 1912 beetles were recovered in 14 different localities of the former town. This species became very abundant in 1913 and 1914 in badly infested sections.

Natick-Weston.—Two hundred larvæ were liberated near the Natick-Weston line in 1910. Larval molt skins were found in a few localities in Natick in 1911. Evidences of the beetles were noticed in 1912 and in 1913, and by 1914 this species had become very abundant in some localities.

Needham.—In 1911, 100 beetles were liberated in woodland off Central Avenue. During 1912 examinations showed them to be present in five or more localities. Data secured in 1913 and 1914 indicated that the species was spreading and increasing rapidly.

Newbury.—During 1910, 88 beetles were liberated in badly infested woodland near Byfield Station. In 1912 they were recovered in several sections throughout the town. Later reports show them to be quite common in areas infested by gipsy moths.

Newburyport.—During 1910, 200 beetle larvæ were liberated in woodland near West Newbury line. Larval molt skins were found in several locations in 1912. In 1913 and 1914 the beetles were very abundant in all the woodland areas.

Newton.—In 1908, 100 beetle larvæ were liberated, and in 1909 400 more were colonized in two other localities. During 1910 they were recovered in and around the colonies. As a result of examinations in 1911 they were found in most of the wooded sections of the city, and later reports indicate that they are quite common in all the districts infested by gipsy moths.

Norfolk.—Ninety beetles were liberated in the western part of this town near Populatic Pond in 1914. Later they were recovered in localities around the colony.

North Andover.—In 1910, 100 beetles were liberated in badly infested woodland off Osgood Street. Scouting in 1912 showed them to be present in a number of localities. In 1913 and 1914 they were reported numerous, and in some cases the larvæ had consumed nearly all the gipsy-moth pupæ on the trees 8 feet from the ground.

Northboro.—During 1913, 190 beetle larvæ were liberated near the Metropolitan Aqueduct. As a result of examinations in 1914 they were found to be present in a number of localities.

North Reading.—In 1910, 200 beetle larvæ were liberated in woodland one-half mile from the State road. They were recovered in a few separated woodlands in 1911. During 1912 this species was quite common in a number of localities, and later reports indicate that they are abundant in all the woodland areas.

Norton.—During 1914, 95 beetles were liberated in the eastern part, and 90 more in the northern part of the town.

Norwell.—*C. sycophanta* beetles were found in the northwestern part of the town in 1912. In 1913, 308 beetle larvæ were liberated in woodland off Main Street, in a rather heavy gipsy-moth infestation. Examinations made later in the year showed them to be present in many localities and in 1914 rapidly increasing.

Norwood.—No beetles were liberated in this town, but they were found in one locality in 1912. Scouting in 1913 showed them to be present in all sections of the town, and in 1914 they were found to be abundant in several wooded areas.

Peabody.—Fifty beetles were liberated in a badly infested woodland in 1907. In 1909, 100 beetles were liberated in woodland near Middleton Paper Mills, 100 beetle larvæ off Birch Street, and 200 larvæ in woodland off West Street, near West Peabody Station. Several woodlands were examined in 1911 and molt skins were found in many locations. During 1912 the adults of this species were seen in large numbers by the inhabitants of West Peabody. Evidence of the beetles' good work was seen in all localities in 1913 and 1914.

Pembroke.—No liberations were made here, but examinations in 1913 showed them to be present in all localities, being well established in the southern part of the town. In 1914 they were more common in most sections where gipsy moths were present in sufficient numbers.

Peppercll.—No beetles were liberated here, but several woodlands were examined in 1913, and larval molt skins were found in a few localities. In 1914 this species was common and doing efficient work in all the woodland areas.

Phillipston.—No liberations were made here, but in 1914 three beetles were seen in the northern section of the town about 1½ miles south of South Royalston Station. These undoubtedly dispersed from the colony liberated at East Templeton in 1913.

Plymouth.—In 1911, 21 beetles and 135 beetle larvæ were liberated on the estate of Mr. B. M. Watson. They were recovered in and around the colony in 1913. Examinations in 1914 showed them to be present in moderate numbers in the northern and central parts of the town.

Plympton.—No liberations were made here, but in 1914 larval molt skins were found in all sections of the town where gipsy moths were present in sufficient numbers.

Princeton.—In 1913, 195 beetle larvæ were liberated in woodland off East Princeton road. During 1914, 180 beetles were liberated at John Chandler's farm, on Princeton-West Sterling road. Later reports show this species to be increasing and spreading satisfactorily.

Provincetown.—In 1914, 100 beetles were liberated in badly infested woodland in Province Lands.

Quincy.—During 1909, 200 beetle larvæ were liberated in woodland off South Street. In 1910 the adults and larvæ were found in abundance in and around the colony; 134 beetle larvæ were added to this colony in 1911. This species was recovered in 1912 in several localities far remote from the site of the original colony. In 1913 and 1914 they had continued to increase and spread rapidly.

Randolph.—No liberations were made here, but larval molt skins were found in a number of sections throughout the town in 1913. A slight increase and spread was noted in 1914.

Raynham.—In 1913, 100 beetles were liberated in woodland at the corner of Forest and Locust Streets. During 1914, 100 beetles were colonized in the central part of the town. This species is spreading rapidly and doing good work in limited localities.

Reading.—No colonies have been liberated here, but larval molt skins were found in the southeastern and central parts in 1910. Scouting in 1911 showed them to be present over the whole area, and in some cases quite numerous. In 1912 larvæ were found commonly throughout. Later reports indicate that they are very numerous and doing efficient work in the infested areas.

Revere.—During 1908, 300 beetle larvæ were colonized in infested woodland on Oak Island. Some visits were made in and around the colony in 1911 and they were seen in large numbers. Later reports indicate that this species is well established.

Rockland.—In 1913, as a result of scouting several woodlands in various parts of the town, it was found that larval molt skins were present in several widely separated districts. During 1914 the beetles had increased rapidly and were doing very efficient work in gipsy-moth infested areas.

Rockport.—In 1910, 200 beetle larvæ were liberated in woodland in the rear of Manning Park. Larval molt skins were found present in several widely separated districts in 1912. During 1913 and 1914 they had become quite common in a number of localities.

Rowley.—Two hundred beetle larvæ were liberated in infested woodland off the Newburyport Turnpike in 1910. During 1912 several examinations were made and it was found that the beetles were present in several localities. Later reports indicate that the species is present in all sections where gipsy moths are found in sufficient numbers.

Rutland.—No liberations were made here, but a few beetles were reported from the eastern part of the town in 1914.

Salem.—No colonies have been liberated in this city, but in 1910 an examination showed them to be present over a large area in the southern part of the city. Scouting in 1911 indicated that they had increased and spread over a much larger area. This species at the present time is common in all the infested districts.

Salisbury.—In 1910, 200 beetle larvæ were liberated in infested woodland, and during 1912 they were recovered in several of the wooded areas. In 1913 and 1914 the species was common in all sections of the town and quite a number were seen around the cottages at Salisbury Beach.

Sandwich.—No beetles were liberated in this town, but as a result of scouting in 1914 it was found that they were present in small numbers in the southeastern and southern parts.

Saugus.—During 1906, 49 beetles were liberated in woodland in the northern section. In 1907, 33 beetles were liberated in infested woodland north of the former gipsy-moth laboratory at North Saugus. During 1911, 34 beetles were seen by Mr. C. W. Collins in a small area in the above district. Two hundred and fifty beetles to be used for transplanting were collected in a small woodland in the northern part of the town in 1913, showing that the beetles were quite numerous. This species has spread rapidly and was well established in all parts of the town in 1914.

Scituate.—In 1911, 835 beetle larvæ were liberated in a woodlot at the corner of Elm and Main Streets. Examinations in 1912 showed them to have multiplied and spread quite a distance from the center of the colony. Later reports indicate that they had dispersed to all parts of the town and were well established.

Sharon.—One hundred beetles were liberated in woodland near Sharon Sanitarium in 1913. During 1914 several localities were scouted and larval molt skins were found in a number of infested districts.

Sherborn.—During 1910, 200 beetle larvæ were liberated in infested woodland off Main Street. Examinations were made in scattered woodlands throughout the town in 1913 and larval molt skins were recovered in several localities. In 1914 they continued to increase and spread and had become well established.

Shirley.—No liberations were made here, but examinations made in 1913 and later reports in 1914 showed the beetles to be present in several separated districts.

Shrewsbury.—In 1913, 250 beetle larvæ were liberated in an apple orchard off Oak Street and 90 adults in the northern part of the town in 1914. As a result of scouting in 1914, it was found that this species was present in all locations where gipsy moths were present in sufficient numbers.

Southboro.—No colonies were liberated here, but in 1913 beetles were found in one locality in the eastern section. During 1914 they had increased and spread to other localities.

Sterling.—During 1913, 200 beetle larvæ were liberated in woodland near the post office. In 1914 larval molt skins were found in all parts of the town, but in small numbers, showing that the beetles had spread and will in time become abundant.

Stoneham.—In 1908, 75 beetles were liberated in woodland off Franklin Street. During 1909 a few of these were recovered. Larval molt skins were found in the eastern and southern parts of the town in 1910. In 1911 and 1912 this species had increased and spread throughout, being very abundant in some localities. Since that time the beetles have become abundant in all gipsy-moth infested areas.

Stoughton.—During 1911, 100 beetles were liberated in infested woodland off Turnpike Street. In 1914 larval molt skins were found in one locality. Infestations in most sections of the town were very light, hence the slow increase of beetles.

Stow.—Eighty-six beetles were liberated in this town in 1910. In 1912 larval molt skins were found in 11 or more separated localities. This species had become well established in 1913 and 1914 and could be found very abundant in some sections of the town.

Sudbury.—In 1910, 200 beetle larvæ were liberated in woodland in East Sudbury. Larval molt skins were recovered in a few localities in 1911, and in 1912 had increased and spread to most sections of the town. Reports received in 1913 and 1914 show this species to be present in all sections and in some cases very abundant.

Swampscott.—During 1908, 175 beetle larvæ were liberated in woodland off Danvers Street and 200 larvæ were colonized north of the Ocean House. In 1910 beetles were recovered in and at some distance from the colonies. This species had increased and spread to a number of localities in 1911 and 1912. Later reports indicate a similar increase and spread.

Taunton.—In 1913, 100 beetles were liberated off Bay Street, and in 1914, 95 adults were colonized in woodland in the southeastern part of the city. Recoveries were made near the colonies in 1914.

Templeton.—During 1913, 200 beetle larvæ were liberated off Petersham Road. Beetles were recovered in and near the colony in 1914.

Tewksbury.—In 1908, 100 beetle larvæ were liberated in woodland infested by gipsy moths. During 1910, 100 beetles were liberated off Shawsheen Avenue and 200 larvæ near Prospect Hill. In 1912 larval molt skins were recovered in 12 or more widely separated localities. Since that time the beetles have spread and become quite abundant in a number of the infested woodlands.

Topsfield.—In 1910, 180 beetle larvæ were liberated off High Street. During 1911 some scouting was done and larval molt skins were found in several woodlands. During 1912 molt skins were found in eight or more different localities. Further reports in 1913 and 1914 showed that the beetles had increased and become well established throughout.

Townsend.—No liberations were made in this town, but a few molted skins were found in two well-separated localities in 1913. Reports from here in 1914 show that the beetles were very plentiful, and could be found in most of the infested areas.

Tyngsboro.—No beetles were liberated here, but in 1912 several woodlands were examined, and larval molt skins found in a number of well-separated localities. Further data secured in 1913 and 1914 indicated that the beetles

had increased extensively, and results of their work were becoming very evident.

Wakefield.—No beetles were colonized here, but in 1909 they were found in the eastern part of the town, and in 1910 could be found in various localities. During 1911 and 1912 they had increased and spread throughout, and are now assisting greatly in lessening the damage done by the gipsy moth.

Walpole.—In 1913, 100 beetles were liberated in a wood lot off North Street. As a result of scouting in 1914, it was found that this species was present in several localities throughout the town.

Waltham.—During 1908, 100 beetle larvæ were liberated off Lake Street. In 1910 they were recovered in and at some distance from the original colony. During 1911 a general scout was made, and molt skins were found in most of the woodlands visited. Since that time the beetles have become well established, and are very abundant in some localities.

Wareham.—No liberations were made here, but as a result of scouting during 1914 the species was found to be present in a few localities in the northwestern part of the town.

Watertown.—No beetles were liberated, but evidences of their presence were noted in several localities in 1911. Since that time they have increased and spread throughout all the woodland areas.

Wayland.—During 1909, 200 beetle larvæ were liberated in infested woodland off Poor Farm Road. In 1910 they were recovered in and around the original colony. During 1911 and 1912 the beetles had spread and become well established in the infested areas. Further reports indicate that they are still increasing and have become quite abundant in several localities.

Wellesley.—In 1908, 223 beetles were liberated in infested woodland near Wellesley Farms Station. In 1909 they were recovered in and at some distance from the original colony, while in 1910 they were scattered over a larger area. During 1911 larval molt skins were recovered in practically all parts of the town. In 1912 the beetles had increased to such an extent that over 2,000 larvæ were collected under burlaps for further colonization without depleting the stock. In 1913, 3,500 beetle larvæ were collected in a limited area of the town, and during 1914 beetles were collected in large numbers for recolonization.

Wenham.—In 1908, 12 beetles and 75 beetle larvæ were liberated off Cherry Street. During 1909, 73 beetles and 100 beetle larvæ were colonized off Grapevine Road. In 1910 beetles were found in and at quite a distance from the original colonies. During 1911 and 1912 the species had increased and spread over large areas. Since that time they have become well established, and in some localities very abundant.

Westboro.—No liberations were made here, but in 1914 beetles were found in a number of localities throughout the town.

West Boylston.—In 1914, 90 beetles were liberated in infested woodland off Prescott Street. During the late summer larvæ were seen in large numbers in and around the colony.

West Bridgewater.—No beetles were liberated here, but in 1914 some scouting was done, and larval molt skins were found in the southwestern part of the town.

Westford.—During 1910, 100 beetle larvæ were liberated in the northern part of the town. Examinations in 1912 showed that the beetles had spread over a rather large area in the eastern section. In 1913 and 1914 further reports indicated that they had increased and were becoming quite numerous.

Westminster.—In 1913, 100 beetles and 200 beetle larvæ were liberated near Bean Porridge Hill, and in 1914, 87 adults were colonized off Westminster Hill

Road. Scouting was done in 1914, and this species was recovered in and at some distance from the original colonies.

Weston.—During 1909, 200 beetle larvæ were liberated in woodland near railroad station. Several larval molt skins were found in the area surrounding the colony in 1910. In 1911 the beetles had spread to all sections, and in some cases quite numerously. Later reports indicate that they have become well established in all parts of the town.

West Newbury.—Two hundred beetle larvæ were liberated on Pipestave Hill in 1910. Scouting in 1912 resulted in finding molt skins in several well separated localities. Later data secured show that they are very common in all the infested woodlands.

Westwood.—In 1910, 200 beetle larvæ were liberated in badly infested woodland, and in 1911, 100 beetles were colonized in woodland off Canton Street. Several woodlands were scouted in 1912, and molt skins were found over the entire area. Since that time this species has become common throughout.

Weymouth.—During 1909, 200 beetle larvæ were colonized in woodland off Commercial Street. In 1910 molt skins were found abundant in and around the colony. During 1911 and 1912 the beetles had become well distributed throughout, and in 1913 and 1914 they had increased extensively.

Wilmington.—Two hundred beetle larvæ were liberated near the central part of the town in 1910. In 1911 it was found that the beetles had spread throughout. During 1913 and 1914 they had become so numerous that it was possible to collect many adults and larvæ for further colonization work.

Winchester.—In 1906, 41 beetles were liberated off High Street. During 1910 larval molt skins were found quite a distance from the original colony. Examinations in 1911 showed that the beetles had dispersed over a greater part of the town and since that time have continued to increase.

Woburn.—During 1907, 97 beetles were liberated in woodland near North Woburn. In 1909 beetles were found in the colony, and larval molt skins were found a mile distant. Data secured in 1910 and 1911 showed that the beetles had increased considerably and had dispersed to all sections of the city. Since that time this species has continued to increase, and is common in all the woodland areas infested by gipsy moths.

Worcester.—In 1913, 150 beetle larvæ were liberated in an apple orchard at the corner of Pleasant and Moreland Streets. Larval molt skins were found quite abundantly in the western part of the city in 1914, and a colony of 90 beetles was liberated the same year near Lake Quinsigamond.

Wrentham.—In 1914, 90 beetles were liberated in the northern part of the town, off Bennett Street.

New Hampshire.

Allenstown.—No colonies were liberated in this town, but in 1913 beetles were found in the southern part. In 1914 they had spread to all sections.

Alton.—In 1914, 90 beetles were liberated in this town near Spring Haven Station, 90 north of Alton Station, and 90 near Merry Meeting Pond, the last being colonized by Prof. W. C. O'Kane.

Amherst.—Although no colonies were liberated in this town, evidence secured in 1913 showed that the beetles were present in 10 or more widely separated localities, and in 1914 had become quite common.

Andover.—In 1914 beetles were found in the eastern part of the town, although no liberations were made.

Atkinson.—Larval molt skins were found in several different localities in this town during 1912. Later reports show them to have become well established.

Auburn.—In 1913 beetles were found present in several localities and during 1914 they had become quite common.

Barnstead.—During 1914, 42 beetle larvæ were liberated in the central part of this town by Prof. W. C. O'Kane. Later they were recovered in the eastern part, where they had spread from other towns.

Barrington.—Although no colonies were liberated here, larval molt skins were found in several sections during 1914.

Bedford.—Scouting during 1913 showed that the beetles were present in several areas and in 1914 they had become quite numerous.

Boscawen.—No liberations were made here, but beetles were found in two widely separated localities in 1914.

Bow.—In 1913, 85 beetles were liberated in woodland near Bow Mills. During 1914 they were found in a number of well-separated sections.

Brookfield.—During 1914, 100 beetles were liberated 2 miles west of Sanbornville Station, 77 on road to Copplecrow Mountain (4 miles from Sanbornville Station), and 56 beetle larvæ one-half mile north of Brookfield Center. The two latter colonies were liberated by Prof. W. C. O'Kane.

Brookline.—No colonies were liberated in this town, but larval molt skins were found in the northern part in 1913, and during 1914 they had increased and spread to a number of localities.

Candia.—During 1913 larval molt skins were found in several scattered woodlands, showing that the beetles had dispersed here from other near-by sections. Further data secured in 1914 show that the beetles were common throughout.

Canterbury.—One hundred beetles were liberated in this town in 1913. They were recovered in six widely separated localities in 1914.

Chester.—Beetles were found to be present in a number of localities in this town during 1913 and 1914.

Chichester.—In 1914, 100 beetles were liberated in the southern part of the town by Prof. W. C. O'Kane. Larval molt skins were also found in this section in 1914.

Concord.—In 1913, 85 beetles were liberated in woodland near West Concord post office. During 1914 larval molt skins were found in all the infested woodlands.

Danville.—Examinations of some woodlands in 1913 showed that the beetles had dispersed here, and in 1914 were well distributed over the entire area.

Deerfield.—No liberations were made here, but in 1914 the beetles were common throughout, and in some localities very abundant.

Deering.—During 1914 beetles were found quite abundant in two well-separated localities.

Derry.—During 1912 and 1913 larval molt skins were found in several widely separated localities. Since that time they have become well established throughout.

Dover.—No colonies were liberated here, but in 1913 and 1914 larval molt skins were found in well-separated localities.

Dunbarton.—As a result of scouting in 1914, beetles were found in six well-separated localities.

Durham.—No beetles were liberated here, but in 1913 and 1914 they had become well established in all parts of the town.

Effingham.—During 1914, 100 beetles and 68 beetle larvæ were liberated in this town by Prof. W. C. O'Kane.

Epping.—During 1913 examinations of woodland showed that the beetles had entered this town, and were present over a limited area. They were reported quite common throughout in 1914.

Epsom.—In 1914, 100 beetles were liberated three-fourths of a mile from Short Falls Station by Prof. W. C. O'Kane.

Exeter.—No liberations were made here, but in 1912 beetles were found in the eastern and southern sections. In 1913 and 1914 they had spread to all parts of the town and were increasing extensively.

Farmington.—Examinations in 1914 showed the beetles to be present in eight widely separated localities.

Fitzwilliam.—In 1914, 300 beetles were colonized in three widely separated localities in this town.

Francistown.—In 1914, as a result of scouting, larval molt skins were found in the eastern, southern, and central parts of this town.

Fremont.—No beetles were liberated here, but in 1912 they were found in three different localities in the southern part of the town. In 1913 and 1914 they had become well established in all the infested woodlands.

Goffstown.—During 1913, 100 beetles were liberated in woodland near Sawyers Crossing. Larval molt skins were found in the northern, western, and south-central parts of the town in 1914, and were abundant in some sections.

Gilmanton.—In 1914, 90 beetles were liberated in the northwestern part of the town. Later the same year 61 beetle larvæ were colonized by Prof. W. C. O'Kane.

Greenville.—In 1914 beetles were reported from all sections of the town.

Hampstead.—During 1912 larval molt skins were found in a few localities. Further reports indicate that they are well established throughout the town.

Hampton.—Examinations of woodlands during 1912 showed that the beetles had dispersed into the town. In 1913 they were found quite commonly in several localities, and during 1914 they were well established in all the woodland areas.

Hampton Falls.—Beetles were found in small numbers in this town during 1912, and in 1913 and 1914 they were reported very abundant in some localities.

Henniker.—In 1914, 54 beetles were liberated in the northwestern part of this town. Later in the year they were recovered in the northeastern, eastern, and southern sections .

Hollis.—In 1912 beetles were found in four or more separated localities. Since that time they have increased and spread to all the infested woodlands.

Hooksett.—Eighty-five beetles were liberated here in 1913. Later in the year larval molt skins were found in a few scattered localities, indicating that the beetles had also spread here from neighboring towns. During 1914 they had become well established throughout.

Hopkinton.—During 1913, 85 beetles were liberated here. In 1914 they were found in the southeastern, eastern, and northwestern parts of the town.

Hudson.—A number of localities were scouted in this town in 1912 and 1913, and larval molt skins were found in many sections. In 1914 they had continued to increase and spread to all infested areas.

Kensington.—Evidences of the beetles' presence were found in this town during 1912. Since that time they have increased and spread to all the infested woodlands.

Kingston.—Beetles were found present here in several localities in 1912. During 1913 and 1914 they had increased and dispersed to all the gipsy-moth infested areas.

Lee.—In 1913 beetles were found in a few separated localities, and during 1914 they had continued to increase and spread to all sections of the town.

Litchfield.—Larval molt skins were found in three or more separated localities in this town during 1913, and in 1914 they had become quite common.

Londonderry.—No liberations were made here, but larval molt skins were found in 12 different localities in 1913. They were reported doing efficient work in the infested woodlands in 1914.

Louden.—In 1914 larval molt skins were found in small numbers in the northeastern part of the town.

Lyndeboro.—Beetles were found in the southeastern part of the town in 1913, and during 1914 they had increased and spread to a number of well-separated localities.

Madbury.—During 1913 beetles had made their appearance in a few localities, and in 1914 they were well distributed throughout the town.

Manchester.—In 1913, 100 beetles were liberated in woodland off Mammoth Road. Later examinations showed that they were present in several localities; this species evidently had spread from nearby towns, and in 1914 was reported common throughout.

Mason.—A few beetles were found in the eastern part of this town in 1913, and in 1914 they were reported from various localities.

Merrimac.—Larval molt skins were found in several widely separated localities in 1913. During 1914 they had become well established throughout.

Middleton.—Seventy-one beetle larvæ were liberated in woodland off Ridge Road by Prof. W. C. O'Kane in 1914.

Milford.—Evidence of the beetles' presence was found in a number of localities in this town during 1914.

Milton.—In 1913, 200 beetle larvæ were liberated off State road near railroad station. During 1914, as a result of scouting, they were found in all parts of the town.

Mont Vernon.—Larval molt skins were found in four well-separated localities in 1913. Since that time this species has continued to increase and is doing efficient work in the infested areas.

Nashua.—In 1912 and 1913 larval molt skins were found in a number of well-separated localities. Reports in 1914 show that they are quite common throughout.

New Boston.—During 1913, 85 beetles were liberated in woodland off Francistown Road, and 85 more near Old Muzzy Hill. In 1914 larval molt skins were found in all sections of the town, being quite abundant in some localities.

New Durham.—In 1914, 90 beetles were liberated in woodland southwest of Davis Station and 104 were colonized by Prof. W. C. O'Kane off road from New Durham to Farmington.

Newfields.—Evidence of the beetles presence in this town was found in several woodlands during 1913 and 1914.

Newington.—A few larval molt skins were found near the Portsmouth line in 1912, and during 1913 the beetles had spread over the greater part of the town. In 1914 they were well established in all the woodlands infested by gipsy moths.

New Ipswich.—In 1913, 100 beetles were liberated in a woodland off King Road. Examinations here in 1914 showed that the beetles were present in a few separated localities.

Newmarket.—Larval molt skins were found in a few localities near the center of the town in 1913. Since that time they have increased and spread to all sections.

Newton.—In 1913 and 1914 beetles were found in a number of separated localities. Later reports indicate that they are still present and increasing.

North Hampton.—Beetles were found present here in a few localities in 1912. Data secured since that time show that they have become well established, being abundant in some localities.

Northwood.—Beetles were found here in a few localities in 1914.

Nottingham.—Scouting in this town during 1913 showed the beetles to be present in the eastern and central sections, and in 1914 they were well distributed throughout.

Ossipee.—In 1914, 32 beetle larvæ were colonized in woodland near Leightons Corner by Prof W. C. O'Kane.

Pelham.—Larval molt skins were found in a number of localities in 1912. During 1913 and 1914 they had increased and spread to all sections of the town.

Pembroke.—During 1913 larval molt skins were found in a few localities in the southern part of the town and in 1914 they were present in most of the infested woodlands.

Pittsfield.—In 1914 larval molt skins were found in the southwestern corner of this town.

Plaistow.—Examinations made here during 1912 and 1913 showed that the beetles were well established, and in 1914 they were found very abundant in some localities.

Portsmouth.—Examinations during 1912 showed that the beetles were present in a few localities, and in 1913 and 1914 they were common throughout the woodland areas.

Raymond.—A careful scout made here in 1913 showed the beetles to be present in several localities. Since that time they have continued to increase and are doing efficient work in the gipsy-moth infested areas.

Richmond.—Beetles were found here in small numbers in 1914.

Rindge.—During 1913, 40 beetles and 102 beetle larvæ were liberated in the southern part of the town, and in 1914, 100 beetles were liberated in a woodland 1½ miles east of West Rindge station.

Rochester.—In 1913 larval molt skins were found in the southern part of the town and during 1914 they were recovered in nine well-separated localities.

Rollingsford.—As a result of examinations in 1914 beetles were found to be common in a number of well-separated woodlands.

Rye.—No liberations were made here, but larval molt skins were found in moderate numbers during 1912 and 1913. In 1914 they had become well established throughout.

Salem.—Beetles were found present in a number of localities in this town during 1912. Since that time they have continued to increase and spread to all the infested areas.

Sandown.—Larval molt skins were found here in a few localities in 1912. In 1913 and 1914 the beetles had dispersed to all the infested areas.

Sandwich-Tamworth.—In 1909, 100 beetle larvæ were liberated near Sandwich-Tamworth line, in woodland which was being defoliated by *Heterocampa guttivitta* Walk. and *Anisota rubicunda* Fab. Gipsy moths had not been found in this region, but it was desired to see whether the beetles would feed on these species and survive the winter. In 1910 and 1913 scouting was done, but no beetles were recovered.

Seabrook.—During 1912 examinations were made in several parts of the town and as a result larval molt skins were found in a few localities. Further data secured in 1913 and 1914 showed that the beetles had increased extensively.

Somersworth.—No liberations were made, but in 1914 larval molt skins were found in a number of well-separated localities.

Southampton.—Scouting in 1913 showed the beetles to be present in a few localities in the western part of the town. Since that time they have continued to increase and spread to the infested woodlands.

Strafford.—During 1913 and 1914 examinations were made in several woodlands, and larval molt skins were found in a few well-separated localities.

Stratham.—In 1912 and 1913 larval molt skins were recovered in a few separated wooded areas of the town, indicating that the beetles had spread from other near-by sections. During 1914 the beetle had become quite common throughout.

Temple.—During 1913, 100 beetles were liberated in infested woodland on Haywood Hill. Scouting in 1914 showed them to be present in a few well-separated localities.

Wakefield.—In 1914, 100 beetles were liberated in woodland on the southwestern shore of Great East Pond, and 100 more were colonized in this town by Prof. W. C. O'Kane.

Weare.—No liberations were made here, but larval molt skins were found in four well-separated localities in 1914.

Webster.—During 1913, 85 beetles were liberated in woodland near Holmes Hill. In 1914 they were recovered in and around the colony, also in the southeastern and southwestern parts of the town.

Wilton.—During 1913, 100 beetles were liberated in infested woodland on Abbott Hill. Examinations in 1914 showed that they were well distributed and quite abundant in some localities.

Windham.—Examinations made here in 1912 showed that the beetles were present in a few localities in the eastern and southern parts of the town. In 1913 and 1914 they had increased considerably, and were doing very efficient work in a number of infested woodlands.

Maine.

In 1908, 100 Calosoma larvæ were shipped by express to Capt. E. E. Philbrook, Portland, Me. They were packed separately in glass tubes with earth and liberated by him in Kittery and Wells. Subsequent examinations have shown that the places selected for making liberations were not particularly suitable for the purpose, as the infestations were so scattering that a sufficient quantity of food was not available for the development of the larvæ. In 1913 scouting and liberation of colonies was done by employees of the Maine Department of Agriculture working in cooperation with the Bureau of Entomology.

Colonies were liberated by the above organization in 1914, but we have no records as to the localities.

Alfred.—Examinations in this town in 1914 showed the beetles to be present in three localities in the central part of the town.

Berwick.—Larval molt skins were found in three localities in the central and southeastern part of the town in 1914.

Biddeford.—Beetles were recovered in three well-separated localities in 1914.

Dayton.—Larval molt skins were found in the north-central part of the town in 1914.

Eliot.—A few beetle larvæ were found here in 1913, and in 1914 they had become common in all parts of the town.

Kennebunk.—In 1914 beetles were reported from two localities in this town.

Kennebunkport.—The gipsy-moth infestation was rather light in this town in 1914, but beetles were found in one locality.

Kittery.—In 1908, 140 beetle larvæ were liberated in three different localities in this town. Scouting was done in 1913 and molt skins were recovered. During 1914 they had spread to all sections and were increasing extensively.

Lyman.—Larval molt skins were found in two localities during 1914.

North Berwick.—In 1914 as a result of scouting larval molt skins were found in two localities in the eastern part and two in the northern part of the town.

Portland.—During 1913, 27 beetles were liberated in woodland near St. Joseph's Academy. They were recovered in the city in 1914.

Saco.—Larval molt skins were found in one locality in the central part of the town in 1914.

Sanford.—In 1914 beetles were found to be present in four widely separated localities.

Shapleigh.—Examinations here in 1914 showed that the beetles were present in three localities.

South Berwick.—Beetle larvæ were found quite abundant in all the areas infested by gipsy moths in 1914.

Wells.—In 1908, 30 beetle larvæ were liberated in this town. In 1914 larval molt skins were recovered in five widely separated localities.

York.—During 1908, 30 beetle larvæ were liberated in the town and 127 adults were colonized in another locality in 1913. In 1914 beetles were recovered in several localities throughout.

Rhode Island.

Cumberland.—In 1913, 200 beetle larvæ were liberated in a gipsy-moth infested woodland near Diamond Hill Reservoir. They were recovered in and around the colony in 1914.

Newport.—During 1914, 110 beetles were liberated in woodland on Miantonomi Hill.

Providence.—In 1913, 170 beetles were liberated in this city; 85 in infested willows off Kay Street, and 85 in Davis Park. They were recovered in and at some distance from the colonies during 1914.

Connecticut.

Stonington.—In 1914, 220 beetles were liberated in this town in two localities where *Malacosoma americana* were very abundant, and gipsy moths had been present.

Thompson.—No liberations were made here, but beetles were found in small numbers in 1914 as a result of spread from Massachusetts towns.

ECONOMIC IMPORTANCE OF CALOSOMA SYCOPHANTA.

This insect has now become firmly established in New England. It is reproducing satisfactorily and has already demonstrated that it is a very important factor in the control of the gipsy moth by natural enemies. The beetle is now abundant enough so that it is frequently seen by many residents of the territory where it was first liberated, and a large number of people are familiar with its habits and methods of destroying the gipsy moth. There are a number of very strong

points which increase the usefulness of this insect. The life history of the beetles and the larvæ corresponds very closely to that of the larval and pupal stages of the gipsy moth, so that they are especially adapted to attack this pest. The climbing habits of the Calosoma larvæ enable these creatures to obtain food upon the trees and in this way an opportunity is furnished for the species to increase in large numbers. The fact that the adults commonly live 2 or 3 years, and sometimes 4 years or more, makes it possible for the species to survive under unfavorable conditions. The chances for the species to exist are further increased by the fact that reproduction by the same individuals may occur on alternate years. The species is capable of existing for long periods without food, and passes through hibernation very successfully under New England climatic conditions. All these factors make it an excellent addition to our fauna, and from the results which have been secured from experimental records and in the field it appears that the species at present ranks first among the introduced natural enemies of the gipsy moth. During the summer of 1914 a large amount of field data was secured to determine the relative importance of the different natural enemies of this insect. The results of 1914 indicate that the Calosoma beetle was the most important single factor. The insect continues to spread each year, and in all probability will soon be present throughout the entire territory where the gipsy moth is known to exist. There is no good reason to suppose that it may not spread in small numbers to places outside this territory if sufficient and proper food can be found.

Beetles sent to New Brunswick, Canada, survived the winter satisfactorily, and the same is true of specimens forwarded to New Mexico, which indicates that the insect is able to survive under quite different climatic conditions.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 252

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER August 10, 1915

LIFE HISTORY OF THE CODLING MOTH IN MAINE

By

E. H. SIEGLER and F. L. SIMANTON, Entomological Assistants, Deciduous Fruit Insect Investigations

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INTRODUCTION.

A temporary field station of the United States Bureau of Entomology was established at Winthrop, Me., in the spring of 1913, under the direction of Mr. A. L. Quaintance, in charge of deciduous fruit insect investigations. Mr. E. H. Siegler, of the Bureau of Entomology, was assigned to this station for the purpose of studying the life history of the codling moth (*Carpocapsa pomonella* L.) under Maine conditions. Owing to the transfer of Mr. Siegler in 1914 to another station, Mr. F. L. Simanton was detailed to complete the investigations. The records of the observations, herewith rèported, cover the seasons of 1913 and 1914, during part of which time the writers were assisted by Mr. E. R. Van Leeuwen.

In order to ascertain the variations in the life history of the codling moth under diverse climatic conditions, investigations have now been completed in widely separated districts, such as Maine and New Mexico, as well as in representative intermediate localities. The methods of study have been essentially the same wherever the work has been undertaken. In this bulletin a detailed account of the life history of the codling moth is reported as well as brief mention of the means of control.

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DEFINITION OF TERMS.

The following terms and definitions have been adopted for this report.

The term brood is used for any stage of any generation of the insect. Thus, first-brood larva refers to a larva of the first generation; spring-brood larva has reference to a larva of either the first or second generation.

Generation is used to include all of the stages of the insect, from the egg to the adult stage.

The life cycle of a generation herein recorded includes the time from the deposition of the egg until the emergence of the moth.

The complete life cycle includes the time from the deposition of the egg of one generation to the deposition of the egg of the next generation.

The term wintering larvæ has reference to the larvæ which winter in the larval stage. It includes all larvæ which do not transform during the same season as hatched.

The wintering larvæ transform in the spring to pupæ, known as spring-brood pupæ (spring pupæ). These in turn transform to spring-brood moths (spring moths). The spring pupæ and spring moths, although the first to appear in the calendar year, are not designated as first-brood pupæ and first-brood moths. The first-brood pupæ and the first-brood moths appear later in the season and are the pupæ and moths of the first generation. These may be conveniently designated summer pupæ and summer moths.

The terms used for Maine conditions are defined as follows:

Wintering larvæ: Include overwintering larvæ of the first and second broods.

Spring-brood pupæ: Include the pupæ from the overwintering larvæ.

Spring-brood moths: Include the moths from the spring pupæ.

The first generation includes:

1. The first brood of eggs.
2. The first brood of larvæ, which includes
   (a) transforming larvæ;
   (b) overwintering larvæ.
3. The first brood of pupæ, or summer pupæ.
4. The first brood of moths, or summer moths.

The second generation (not complete in Maine) includes:

1. The second brood of eggs.
2. The second brood of larvæ. None of these larvæ transform until the following spring.

SEASONAL-HISTORY STUDIES OF 1913.

The codling-moth life-history investigations were conducted under outdoor conditions, so that the results obtained would represent, as nearly as possible, the normal life of this insect in the field. Accordingly the rearing work was carried on in an open shelter erected for this purpose.

As a basis of comparison the laboratory methods were checked with field observations chiefly by means of banded trees. The apple trees were prepared for banding by removing the loose bark from the trunk and main limbs. A burlap band of three thicknesses and about 5 inches in width was then placed tightly around the trunk about 3 feet above the base and held in place by an 8-penny wire nail. The larvæ were collected from these banded trees every three days. These larvæ hatched and fed under natural conditions, and hence their time of leaving the fruit and their subsequent life history should correspond with those of the larvæ reared by the laboratory methods.

The general method for carrying out the life-history studies is illustrated in Plate II, figure 1. The cages used were large glass battery jars covered with cheesecloth tops, which were held in place by rubber bands. In cage *a* (Pl. II, fig. 1) are shown the racks in which the codling-moth larvæ have spun their cocoons. The details of these racks are illustrated in Plate II, figure 2, and described on page 4. Pupation is recorded daily and after the moths emerge the length of the pupal stage is computed. The moths are transferred daily from cages similar to cage *a* (Pl. II, fig. 1), and confined within cages like cage *b* (Pl. II, fig. 1). The bottom of cage *b* is covered with 3 inches of moist sand and contains fresh apple foliage and a sponge moistened with a sugar solution. The moths deposit their eggs upon the foliage, which is removed each day and the number of eggs recorded. The following data are obtained from cage *b*: (1) Days before egg deposition; (2) time of egg deposition; (3) length of oviposition period; (4) total number of eggs; (5) average number of eggs per female; (6) length of life of male and female moths.

In order to prevent curling, the leaves are placed between two pieces of wire screen until the leaves dry—cage *c* (Pl. II, fig. 1). They are then removed from cage *c* to cage *d* (Pl. II, fig. 1), in which cage the embryological changes and incubation periods are noted. Upon hatching the larvæ are transferred to cage *e* (Pl. II, fig. 1). This cage contains apples placed within a wire container and also the racks in which the larvæ spin their cocoons.

Since the time of entering the fruit is known and since the time of leaving is found by a daily examination of the cocoon racks, the length of the feeding period is thus established. By following the

successive stages of the codling moth through the series of five cages the life cycle is readily ascertained.

It should be explained here that each table is a unit in itself. Successive tables are not necessarily continuations of the life history of all of the same individuals. For example, it will be noted that Table I is a record of the time of pupation of 753 wintering larvæ and that Table II includes observations on the length of the pupal stage of but 483 of these individuals. Differences of this character may be due to natural or artificial causes, such as to death, to accidental injury, to parasites, to the removal of specimens for other purposes, and to accidental escape of the moths during examination.

WINTERING LARVÆ.

The wintering larvæ, as stated in the definition of terms, comprise first and second brood larvæ. These larvæ winter naturally in cocoons (Pl. I, fig. 1), usually beneath the loose bark of trees, in decayed wood, or in other similarly protected places on or about the tree. The larvæ are inactive until spring, when they remodel their cocoons, so as to furnish exit tubes for the moths. (See Pl. I, fig. 2.) The exit tube, which varies in length according to the exigency, assists the moth in successfully emerging from the cocoon.

The codling-moth larvæ used at the laboratory were collected early in the spring of 1913. These larvæ were secured from cider mills where they had spun up beneath the flooring and in other concealed places. The larvæ were then allowed to form new cocoons in racks such as are shown in the illustration (Pl. II, fig. 2).

These racks consist of two strips of soft wood, to the lower of which three narrow crosspieces are glued—one at each end and one in the middle. A thin piece of mica is then placed between these crosspieces and the top strip and the whole is held together by two clamps. This makes it possible to remove the top strip and to observe the specimens through the mica. Referring to the illustration, it will be seen that there are artificial cells or compartments. The walls of these were first outlined with a little glue over which sawdust was sprinkled. Although more than one larva frequently spins up within the same chamber the artificial barriers serve to keep the larvæ somewhat separated. Such separation facilitates the recording of the observations.

SPRING BROOD OF PUPÆ.

Time of pupation.—Daily observations of the wintering larvæ were taken and as each larva pupated its number was recorded upon the rack directly below the pupa. (Pl. II, fig. 2.) In Table I is shown

CHART ILLUSTRATING THE LIFE HISTORY OF THE CODLING MOTH IN MAINE.

FIG. 1.—Overwintering larva in cocoon. FIG. 2.—Cocoons remodeled by overwintering larvæ to form exit tubes. The upper cocoon contains a spring-brood pupa; the lower, a pupal skin from which the moth emerged. FIG. 3.—A spring-brood moth. FIG. 4.—A spring-brood moth ovipositing on leaf, showing first-brood eggs. FIG. 5.—A wormy apple containing a first-brood larva. FIG. 6.—Cocoons of first-brood larvæ, one of which transformed to pupa. FIG. 7.—First-brood moth ovipositing on leaf, showing second-brood eggs. FIG. 8.—An apple showing where a second-brood larva entered the side. Time to spray, as soon as petals drop. Too late to spray, calyx cup closed. (Original.)

APPARATUS EMPLOYED IN THE REARING OF THE CODLING MOTH IN MAINE.

FIG. 1.—*a*, Pupation and moth emergence cage; *b*, oviposition cage; *c*, leaf-pressing cage; *d*, incubation cage; *e*, feeding cage. FIG. 2.—Cocooning rack (three views) in which the larvæ spin their cocoons and pupate. (Original.)

the time of pupation of 753 overwintering larvæ. It will be noted that the first larva pupated May 5, while the last larva under observation did not pupate until July 7. Hence spring-brood pupation extended over a period of about two months. The maximum

FIG. 1.—Diagram showing pupation of the spring brood of the codling moth in 1913 at Winthrop, Me. (Original.)

time of pupation was June 6, when 72 larvæ transformed. The greater part of the larvæ pupated during the first half of June. (See fig. 1.)

TABLE I.—*Time of pupation of overwintering larvæ, Winthrop, Me., 1913.*

Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.
May 5	1	May 31	10	June 13	22	June 26	4
May 6	1	June 1	29	June 14	28	June 27	10
May 10	1	June 2	21	June 15	28	June 28	5
May 14	2	June 3	38	June 16	20	June 29	4
May 17	1	June 4	58	June 17	15	June 30	3
May 18	1	June 5	63	June 18	20	July 1	5
May 23	3	June 6	72	June 19	12	July 2	1
May 24	2	June 7	56	June 20	11	July 3	1
May 25	2	June 8	17	June 21	11	July 7	1
May 26	3	June 9	12	June 22	9		
May 28	4	June 10	44	June 23	6	Total ..	753
May 29	3	June 11	39	June 24	7		
May 30	6	June 12	38	June 25	3		

Length of the pupal stage.—The average length of the pupal stage of 483 individuals, as recorded in Table II, was found to be 19.03 days; maximum, 44 days; minimum, 9 days. By reference to this table it will be seen that as the season advanced the length of the pupal stage was gradually shortened, due to higher average daily temperatures.

TABLE II.—*Length of the pupal stage of spring-brood pupæ, Winthrop, Me., 1913.*

Number of individuals.	Date of pupation.	Length of the pupal stage in specified days.																					
		9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	31
1	May 17																						1
2	May 25																2						
2	May 26																			2			
1	May 28															1							
2	May 29														2								
2	May 30														2								
4	May 31													1	3								
16	June 1												2	8	4	2							
8	June 2												1	3	2	2							
18	June 3												3	5	9							1	
37	June 4											1	2	17	10	4			1	1		1	
42	June 5											1	8	11	19				1		1		1
47	June 6												3	36	4	2		1		1			
35	June 7									1	1	1	12	11	8					1			
13	June 8											2	4	6	1								
10	June 9											2	6	1	1								
18	June 10						1			2	1	10	4										
26	June 11									2	4	13	5		1							1	
27	June 12							1		1	9	16											
17	June 13								1	1	13	1	1										
22	June 14									12	9	1											
21	June 15		1							15	4	1											
16	June 16								1	4	8	1			2								
12	June 17								3	9													
16	June 18						1	4	8		3												
8	June 19							2	4	2													
10	June 20					2	2	2	2	2													
9	June 21			1				6	2														
5	June 22							4				1											
5	June 23						3	1		1													
3	June 24						1	1	1														
3	June 25					2				1													
4	June 26				1		2					1											
8	June 27		1			1	2	4															
3	June 28	1			1			1															
4	June 29						3		1														
1	June 30							1															
3	July 1						1			1	1												
1	July 3									1													
1	July 7				1																		
483	pupæ	1	2	1	2	6	16	27	23	55	53	52	51	99	68	11	2	1	2	5	1	3	1	1

Average length of the pupal stage, 19.03 days.
Maximum length of the pupal stage, 44 days.
Minimum length of the pupal stage, 9 days.

SPRING BROOD OF MOTHS.

Time of emergence of moths.—The first of the spring-brood moths emerged June 18, about two weeks after the petals dropped. The maximum emergence of moths occurred June 27—one month after full bloom. The last of the spring-brood moths issued July 20. The emergence record of 514 moths is given in Table III.

TABLE III.—*Time of emergence of moths of the spring brood, Winthrop, Me., 1913. (See fig. 2.)*

Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.
June 18	2	June 27	74	July 5	10	July 15	4
June 20	5	June 28	27	July 6	14	July 18	1
June 21	10	June 29	39	July 7	14	July 0	2
June 22	15	June 30	32	July 8	5		
June 23	14	July 1	50	July 10	7	Total.	514
June 24	25	July 2	35	July 11	3		
June 25	43	July 3	16	July 12	4		
June 26	25	July 4	34	July 13	4		

Time of egg deposition.—As will be seen in Table IV, the first eggs of the spring-brood moths were laid on June 22, while the last oviposition occurred July 30. Hence the period of oviposition was approximately 1 month. The average number of days from the time of emergence to the time of first oviposition was 4.086 days; maximum, 14 days; minimum, 1 day. The average duration of the oviposition period was 14.086 days; maximum, 26 days; minimum, 1 day. The average number of days from the date of moth emergence to the last date of oviposition was 16.739 days; maximum, 27 days; minimum, 6 days.

FIG. 2.—Diagram showing emergence of the spring brood of moths of the codling moth in 1913 at Winthrop, Me. (Original.)

TABLE IV.—*Oviposition by moths of the spring brood in rearing cages, Winthrop, Me., 1913.*

Cage No.	Number of moths.	Sex. ♂	Sex. ♀	Date of— Emergence of moths.	Date of— First oviposition.	Date of— Last oviposition.	Number of days— Before oviposition.	Number of days— Of oviposition.	Number of days— From date of emergence to last oviposition.
1	2, 5, 10	9	8	June 18, June 20, June 21	June 22	July 7	.....	.....	.....
2	13	9	4	June 22	June 29	July 2	7	4	10
3	13	9	4	June 23	...do....	July 3	6	5	10
4	19	12	7	June 24	...do....	July 9	5	11	15
5	41	16	25	June 25	June 27	...do....	2	13	14
6	24	13	11	June 26	July 3	July 8	7	6	12
7	30	16	14	June 27	June 29	July 14	2	16	17
8	38	12	26	...do....	...do....	July 24	2	26	27
9	24	11	13	June 28	July 1	July 13	3	13	15
10	26	8	18	June 29	...do....	July 22	2	22	23
11	25	14	11	June 30	July 2	July 23	2	22	23
12	25	10	15	July 1	July 3	July 27	2	25	26
13	18	7	11	...do....	...do....	July 22	2	20	21
14	31	16	15	July 2	July 4	...do....	2	19	20
15	14	5	9	July 3	July 5	July 23	2	19	20
16	28	15	13	July 4	...do....	July 22	1	18	18
17	9	6	3	July 5	July 6	...do....	1	17	17
18	13	3	10	July 6	July 8	July 30	2	23	24
19	11	4	7	July 7	July 11	July 29	4	19	22
20	5	3	2	July 8	July 18	July 20	10	3	12
21	5	1	4	July 10	July 17	July 25	7	9	15
22	4	2	2	July 12	July 15	July 20	3	6	8
23	3	1	2	July 13	July 17	July 23	14	7	10
24	4	2	2	July 15	July 21	July 21	6	1	6
Number of male moths	204			Average			4.086	14.086	16.739
Number of female moths	236			Maximum			14	26	27
Total number of moths	440			Minimum			1	1	6

Number of eggs per female.—No attempt was made to isolate fertilized females for the purpose of securing individual egg-laying records. However, by dividing the number of eggs laid by the number of female moths the average was computed. In Table IV it will be seen that 236 female moths were confined with 204 males in 24 cages. A few eggs were laid upon the sides of the cages, but these were not included in the computation. The number of eggs, exclusive of those laid upon glass, was 7,546, which number when divided by 236 gives an average of 31.974 eggs per female.

Length of life of moths.—Observations on the length of the life of 191 male moths and 229 female moths are shown in Table V. The average life of the male moth was 10.685 days; of the female, 12.253 days. Maximum number of days for male moth 34, for female 38; minimum number of days for male moth 2, for female 2.

TABLE V.—*Length of life of male and female moths of the spring brood in captivity; summary of records of 420 individual moths, Winthrop, Me., 1913.*

Male.		Female.		Male.		Female.	
Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.
Days.		*Days*		*Days.*		*Days.*	
2	3	2	1	22	2	22	1
3	7	3	5	23	2	23	5
4	5	4	4	24	0	24	3
5	15	5	12	25	1	25	2
6	15	6	11	26	0	26	1
7	20	7	18	27	2	27	1
8	22	8	13	28	0	28	2
9	24	9	24	29	0	29	2
10	13	10	20	30	1	30	0
11	5	11	20	31	2	31	0
12	7	12	15	32	0	32	2
13	6	13	3	33	0	33	0
14	9	14	19	34	2	34	0
15	5	15	10	35	0	35	0
16	6	16	9	36	0	36	0
17	4	17	6	37	0	37	0
18	1	18	5	38	0	38	1
19	5	19	3				
20	4	20	7		191		229
21	3	21	4				

Average length of life of male moths, 10.685 days; female moths, 12.253 days.
Maximum length of life of male moths, 34 days; female moths, 38 days.
Minimum length of life of male moths, 2 days; female moths, 2 days.

THE FIRST GENERATION.

FIRST BROOD OF EGGS.

Length of incubation.—During the period of oviposition a record of 7,546 eggs was kept. Of this number 7,493 (99.29 per cent) hatched. The average number of days from the time of oviposition to the appearance of the red ring was 2.507; maximum, 5 days; minimum, 2 days. The average time elapsing from the time of oviposition to the appearance of the black spot was 5.580 days; maximum, 7 days; minimum, 4 days. The average incubation period was 8.874 days; maximum, 10 days; minimum, 6 days. The results are given in Table VI.

TABLE VI.—*Length of incubation of first brood of eggs, Winthrop, Me., 1913.*

No. of observation.	Number of eggs.	Date—				Appearance of—		Incubation period.	Number dead.
		Deposited.	Red ring.	Black spot.	Hatched.	Red ring.	Black spot.		
						Days.	*Days.*	*Days.*	
1	.....	June 22	June 26	June 29	July 1	4	7	9	.....
2	1	June 24	June 27	...do.....	...do.....	3	5	7	.....
3	1	...do.....	.....	.....	July 2	.....	.....	8	.....
4	11	June 26	June 28	July 1	July 3	2	5	7	.....
5	1	...do.....	.....	.....	July 4	.....	.....	8	.....
6	10	June 27	June 29	July 2	July 3	2	5	6	.....
7	61	...do.....	.....	.....	July 4	.....	.....	7	1
8	80	June 28	July 1	July 3	...do.....	3	5	6	.....
9	37	...do.....	.....	.....	July 5	.....	.....	7	.....
10	165	June 29	July 2	July 4	...do.....	3	5	6	.....
11	40	...do.....	.....	.....	July 6	.....	.....	7	.....
12	108	June 30	July 3	July 5	...do.....	3	5	6	.....
13	10	...do.....	.....	.....	July 7	.....	.....	7	.....
14	504	July 1	July 3	July 5	...do.....	2	4	6	.....
15	31	...do.....	.....	.....	July 8	.....	.....	7	.....
16	25	...do.....	.....	.....	July 9	.....	.....	8	.....
17	65	July 2	July 4	July 6	July 8	2	4	6	.....
18	730	...do.....	.....	.....	July 9	.....	.....	7	.....
19	20	...do.....	.....	.....	July 10	.....	.....	8	.....
20	716	July 3	July 5	July 7	...do.....	2	4	7	.....
21	46	...do.....	.....	.....	July 11	.....	.....	8	19
22	27	July 4	July 7	July 10	...do.....	3	6	7	.....
23	725	...do.....	.....	.....	July 12	.....	.....	8	.....
24	15	...do.....	.....	.....	July 13	.....	.....	9	4
25	1,040	July 5	July 8	July 12	...do.....	3	7	8	.....
26	21	...do.....	.....	.....	July 14	.....	.....	9	5
27	344	July 6	July 10	July 13	...do.....	4	7	8	.....
28	274	...do.....	.....	.....	July 15	.....	.....	9	.....
29	19	...do.....	.....	.....	July 16	.....	.....	10	3
30	47	July 7	July 10	July 13	July 15	3	6	8	.....
31	9	...do.....	.....	.....	July 16	.....	.....	9	.....
32	1	...do.....	.....	.....	July 17	.....	.....	10	.....
33	153	July 8	July 10	July 14	July 16	2	6	8	.....
34	220	...do.....	.....	.....	July 17	.....	.....	9	.....
35	169	July 9	July 11	July 15	...do.....	2	6	8	.....
36	17	...do.....	.....	.....	July 18	.....	.....	9	5
37	21	July 10	July 12	July 15	...do.....	2	5	8	.....
38	4	...do.....	.....	.....	July 19	.....	.....	9	.....
39	326	July 11	July 13	July 16	...do.....	2	5	8	.....
40	5	...do.....	.....	.....	July 20	.....	.....	9	.....
41	414	July 12	July 14	July 18	...do.....	2	6	8	.....
42	17	...do.....	.....	.....	July 21	.....	.....	9	6
43	123	July 13	July 15	July 19	July 20	2	6	7	.....
44	47	...do.....	.....	.....	July 21	.....	.....	8	.....
45	9	...do.....	.....	.....	July 22	.....	.....	9	1
46	59	July 14	July 17	July 20	...do.....	3	6	8	.....
47	2	...do.....	.....	.....	July 23	.....	.....	9	1
48	54	July 15	July 17	July 21	July 22	2	6	7	.....
49	64	...do.....	.....	.....	July 23	.....	.....	8	.....
50	173	July 16	July 18	July 22	...do.....	2	6	7	.....
51	22	...do.....	.....	.....	July 24	.....	.....	8	2
52	25	July 17	July 22	July 23	...do.....	5	6	7	.....
53	129	...do.....	.....	.....	July 25	.....	.....	8	.....
54	9	July 18	July 22	July 23	...do.....	4	5	7	.....
55	15	...do.....	.....	.....	July 26	.....	.....	8	1
56	10	July 19	July 22	July 24	July 25	3	5	6	.....
57	38	...do.....	.....	.....	July 26	.....	.....	7	.....
58	50	July 20	July 23	July 25	July 27	3	5	7	.....
59	6	...do.....	.....	.....	July 28	.....	.....	8	.....
60	35	July 21	July 24	July 27	...do.....	3	6	7	.....
61	11	...do.....	.....	.....	July 29	.....	.....	8	2
62	40	July 22	July 25	July 27	...do.....	3	5	7	.....
63	7	...do.....	.....	.....	July 30	.....	.....	8	.....
64	20	July 23	July 26	July 29	...do.....	3	6	7	2
65	20	July 24	...do.....	July 30	July 31	2	6	7	.....
66	14	July 25	July 27	...do.....	Aug. 1	2	5	7	.....
67	1	...do.....	.....	.....	Aug. 2	.....	.....	8	.....
68	8	July 26	July 28	Aug. 1	...do.....	2	6	7	.....
69	2	...do.....	.....	.....	Aug. 3	.....	.....	8	1
70	6	July 27	July 29	Aug. 2	...do.....	2	6	7	.....
71	3	...do.....	.....	.....	Aug. 4	.....	.....	8	.....
72	6	July 28	July 30	Aug. 2	...do.....	2	5	7	.....
73	4	July 29	July 31	Aug. 4	Aug. 5	2	6	7	.....
74	3	...do.....	.....	.....	Aug. 6	.....	.....	8	.....
75	1	Aug. 1	Aug. 4	Aug. 7	Aug. 9	3	6	8	.....
Average						2.507	5.580	8.874	53
Maximum						5	7	10	.....
Minimum						2	4	6	.....

FIRST BROOD OF LARVÆ.

Time of hatching.—The earliest first-brood larvæ hatched July 1; the latest hatched August 9. Hence larvæ of the first brood were hatching for a period of over one month. The larvæ were hatching in large numbers from July 7 to July 15, reaching the maximum on July 13, at which time 1,055 larvæ hatched. These records appear in Table VI.

Length of the feeding period of the transforming larvæ.—Three methods for determining the feeding period of the first-brood larvæ were used:

(*A*) *Stock-jar method.* The newly hatched larvæ were allowed to enter fruit known to be free from codling-moth infestation. This fruit was placed in cages similar to cage *e* (Pl. II, fig. 1). As each larva left the fruit its number was recorded upon the cocooning rack directly beneath the cocoon made by the larva. Since the time of entering the fruit was known, the length of the feeding period was thus established.

(*B*) *Watered stock-jar method.* This method was similar to (*A*), except that twigs having two or three apples were placed for a period of two weeks in glass jars containing water. The apples were then pulled and kept under conditions identical with (*A*).

(*C*) *Bagged-fruit method.* Newly hatched larvæ were placed on fruit growing on the tree and the fruit was then covered with perforated paper bags. After a period of two weeks the fruit was removed to the laboratory and kept under conditions identical with (*A*).

In 1913 the number of transforming larvæ reared at the laboratory was 3.8 per cent of the first brood. All larvæ which do not transform during the same season as hatched winter as larvæ and pupate the following spring and are designated spring pupæ.

In Table VII the length of the feeding period of the transforming larvæ of the first brood (stock-jar method) is given. The average number of days of feeding (male and female larvæ) was 20.454; male larvæ, 22.333; female larvæ, 20.200; maximum feeding period, male, 24 days; female, 24 days; minimum feeding period, male, 21 days; female, 17 days.

TABLE VII.—*Length of feeding period of transforming larvæ of the first brood, stock-jar method, Winthrop, Me., 1913.*

No. of observation.	Date of—		Sex of larva.	Days of feeding.	No. of observation.	Date of—		Sex of larva.	Days of feeding.
	Hatching.	Leaving fruit.				Hatching.	Leaving fruit.		
1	July 6	July 30	♂	24	7	July 7	July 31	♀	24
2	July 7	July 25	.....	18	8	July 10	July 30	♀	20
3	July 7	July 26	.....	19	9	July 10	July 31	♀	21
4	July 7	July 27	.....	20	10	July 15	Aug. 3	♀	19
5	July 7	July 28	♂	21	11	July 19	Aug. 5	♀	17
6	July 7	July 29	♂	22					

Average length of feeding period, male and female larvæ, 20.454 days; male, 22.333 days; female, 20.20 days.

Maximum length of feeding period, male and female larvæ, 24 days; male, 24 days; female, 24 days.

Minimum length of feeding period, male and female larvæ, 17 days; male, 21 days; female 17 days.

Table VIII gives a record of the feeding period of the transforming larvæ of the first brood (watered stock-jar method). The average feeding period for male and female larvæ was 24.769 days; for male larvæ, 23 days; female larvæ, 25.142 days; maximum, male, 27 days; female, 31 days; minimum, male, 21 days; female, 20 days.

TABLE VIII.—*Length of feeding period of transforming larvæ of the first brood, watered stock-jar method, Winthrop, Me., 1913.*

No. of observation.	Date of—		Sex of larva.	Days of feeding.	No. of observation.	Date of—		Sex of larva.	Days of feeding.
	Hatching.	Leaving fruit.				Hatching.	Leaving fruit.		
1	July 7	July 29	♂	22	8	July 11	Aug. 3	♀	23
2	July 7	July 30	♂	23	9	July 12	Aug. 2	♂	21
3	July 8	Aug. 2	♀	25	10	July 12	Aug. 3	♂	22
4	July 8	Aug. 3	♀	26	11	July 12	Aug. 7	♀	26
5	July 8	Aug. 8	.....	31	12	July 13	Aug. 2	♀	20
6	July 8	Aug. 8	♀	31	13	July 16	Aug. 10	♀	25
7	July 10	Aug. 6	♂	27					

Average length of feeding period, male and female larvæ, 24.769 days; male, 23 days; female, 25.142 days.
Maximum length of feeding period, male and female larvæ, 31 days; male, 27 days; female, 31 days.
Minimum length of feeding period, male and female larvæ, 20 days; male, 21 days; female, 20 days.

As shown in Table IX, the feeding period of the transforming first-brood larvæ (bagged-fruit method) averaged for male and female 25.818 days; for male larvæ, 23.833 days; female larvæ, 29.250 days. The maximum feeding period for male larvæ was 27 days; female, 34 days. The minimum feeding period for male larvæ was 21 days; for female, 26 days.

By reference to Table XIX, it will be noted that the average feeding period of the transforming larvæ was 23.432 days.

TABLE IX.—*Length of feeding period of transforming larvæ of the first brood, bagged-fruit method, Winthrop, Me., 1913.*

No. of observation.	Date of—		Sex of larva.	Days of feeding.	No. of observation.	Date of—		Sex of larva.	Days of feeding.
	Hatching.	Leaving fruit.				Hatching.	Leaving fruit.		
1.....	July 3	July 27	.....	24	7.....	July 5	Aug. 8	♀	34
2.....	July 4	July 30	♀	26	8.....	July 7	July 31	♂	24
3.....	July 4	July 31	♀	27	9.....	July 7	July 31	♂	24
4.....	July 4	July 31	♂	27	10.....	July 8	July 30	♂	22
5.....	July 4	Aug. 3	♀	30	11.....	July 10	July 31	♂	21
6.....	July 5	July 30	♂	25					

Average length feeding period, male and female larvæ, 25.818 days; male, 23.833 days; female, 29.250 days.
Maximum length feeding period, male and female larvæ, 34 days; male, 27 days; female, 34 days.
Minimum length feeding period, male and female larvæ, 21 days; male, 21 days; female, 26 days.

Length of the feeding period of wintering first-brood larvæ (stock-jar method).—Table X records the feeding period of 390 larvæ. As will be noted, the feeding period for all male and female larvæ averaged

25.925 days; maximum, 49 days; minimum, 16 days. The average feeding period for 140 male larvæ was 24.621 days; maximum, 46 days; minimum, 16 days. The average for 207 female larvæ was 26.371 days; maximum, 44 days; minimum, 19 days. Remainder of larvæ—sex undetermined.

TABLE X.—*Length of feeding period of wintering larvæ of the first brood, stock-jar method, Winthrop, Me., 1913.*

[Figures in parentheses ( ) denote sex undetermined.]

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.																	
		16		19		20		21		22		23		24		25		26	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
4	July 5														1				
8	July 6											1			3	2			
9	July 7							1		1			1	(1)	1		2		
18	July 8									1	1			2	1	2		2	1
10	July 9									1					2		1		1
39	July 10					1	1					3	4(1)	4	4	1	(1)	2	2
13	July 11										2	1	1			2	1		1
25	July 12								2				1	3		1	3	2	2
13	July 13							2		1		1			2			1	1
13	July 14					2		1		3	1	(1)			1	1	1(1)		1
41	July 15			1	1	3	4	3	2	1	5	3	2	2	3(2)	1	1	(1)	2
6	July 16				1			2			1	(1)							
16	July 17										2		2	3			1		
22	July 19			1		4	1	3	3(1)		1	2	1		1				
28	July 20	1			1				2	1	2	1	4	2(2)	1		2		2
15	July 21							1				2	1	2	1		1		3
12	July 23											(1)	3	3	1			1	
13	July 24										1			3	2	1			2
14	July 25									1									
11	July 26					(1)					2			1	2				
4	July 27																1		1
16	July 28									1	1			1	2	1	1		2
13	July 29					1		2		2		1	(1)	(1)				(2)	1
12	July 30							1		1	1					3		1	
2	July 31																		
2	Aug. 1																		
3	Aug. 3									1					(1)				
2	Aug. 4																		2
5	Aug. 6															(1)	1		
1	Aug. 9														(1)				
390 ♂ and ♀		1	0	2	3	11	6	16	9	14	21	15	20	26	28	15	16	9	24
Sex undetermined						1		1				5		8		3		3	
Total		1		5		18		26		35		40		62		34		36	

TABLE X.—*Length of feeding period of wintering larvæ of the first brood, stock-jar method, Winthrop, Me., 1913*—Continued.

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.																	
		27		28		29		30		31		32		33		34		35	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
4	July 5	....	1	....	....	1	....	....	....	....	1	....	....	....	....	....	....	....	....
8	July 6	....	....	....	....	....	....	....	....	....	....	....	....	....	2	....	....	....	....
9	July 7	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....
18	July 8	....	....	3	1(2)	....	....	....	....	....	....	....	....	2	....	....	....	....	....
10	July 9	2	1(1)	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
39	July 10	....	1	....	3	1	1	(1)	4	....	....	1	....	....	....	....	1	....	....
13	July 11	....	....	1	....	....	....	....	1	....	....	....	....	....	....	....	2	....	....
25	July 12	(1)	1	1	4	....	....	....	....	....	....	....	....	....	....	....	2	(1)	....
13	July 13	....	1	....	....	....	....	....	....	1	(1)	....	....	....	....	....	2	....	....
13	July 14	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
41	July 15	....	....	....	....	....	1	....	....	....	1	....	....	....	....	....	1	....	....
6	July 16	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....
16	July 17	....	....	1(1)	2	....	....	....	2	....	1	....	....	....	....	....	1	....	....
22	July 19	....	....	....	....	....	....	....	1	....	1	....	....	....	....	....	1	(1)	....
28	July 20	....	2	1	....	....	....	....	2	1	....	....	....	....	....	....	....	(1)	....
15	July 21	(1)	1	(1)	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....
12	July 23	....	1	....	....	....	....	....	....	....	....	....	2	....	....	....	....	....	....
13	July 24	....	....	....	....	....	1	....	....	1	....	....	....	....	....	....	1	....	1
14	July 25	....	....	3	4	....	....	1	1	....	....	1	....	....	1	....	....	....	....
11	July 26	....	....	....	....	....	....	....	1	1	1	....	....	....	....	....	....	....	1
4	July 27	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
16	July 28	....	....	....	....	....	2	....	....	....	2	....	....	1	....	....	1	....	....
13	July 29	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
12	July 30	....	....	....	1	....	1	....	....	....	....	....	....	....	1	....	....	....	....
2	July 31	....	....	....	....	(1)	....	....	....	....	....	(1)	....	....	....	....	....	....	....
2	Aug. 1	....	....	....	....	....	....	....	1	....	....	....	(1)	....	....	....	....	....	....
3	Aug. 3	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
2	Aug. 4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
5	Aug. 6	....	....	....	....	....	1	....	....	....	(1)	....	....	(1)	....	....	....	....	....
1	Aug. 9	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
390 ♂ and ♀		3	10	11	15	2	8	2	13	4	7	3	2	3	4	0	12	0	2
Sex undetermined		3		4		1		1		2		2		1		.....		3	
Total		16		30		11		16		13		7		8		12		5	

TABLE X.—*Length of feeding period of wintering larvæ of the first brood, stock-jar method, Winthrop, Me., 1913*—Continued.

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.															
		36		37		38		39		40		43		44		46	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
4	July 5																
8	July 6																
9	July 7					(1)											
18	July 8																
10	July 9																
39	July 10					(1)							1				
13	July 11			(1)													
25	July 12									1							
13	July 13																
13	July 14																
41	July 15		1														
6	July 16																
16	July 17																
22	July 19																
28	July 20																
15	July 21																
12	July 23																
13	July 24																
14	July 25	(1)			1												
11	July 26							(1)									
4	July 27				1												
16	July 28															1	
13	July 29				1			1									
12	July 30					1									1		
2	July 31																
2	Aug. 1																
3	Aug. 3																
2	Aug. 4																
5	Aug. 6																
1	Aug. 9																
390 ♂ and ♀		0	1	0	3	0	1	1	0	1	0	0	1	0	1	1	0
Sex undetermined		1		1		2		1									
Total		2		4		3		2		1		1		1		1	

Average feeding period, 390 male and female larvæ, 25.925 days; 140 male larvæ, 24.621 days; 207 female larvæ, 26.371 days.

Maximum feeding period, 390 male and female larvæ, 49 days; 140 male larvæ, 46 days; 207 female larvae, 44 days.

Minimum feeding period, 390 male and female larvæ, 16 days; 140 male larvæ, 16 days; 207 female larvæ, 19 days.

Length of the feeding period of wintering first-brood larvæ (watered stock-jar method).—As shown in Table XI, the average feeding period of 260 male and female larvæ was 26.569 days; maximum, 41 days; minimum, 19 days. The average for 111 male larvæ was 26.315 days; maximum, 40 days; minimum, 19 days. The average feeding period for 123 female larvæ was 26.463 days; maximum, 41 days; minimum, 20 days. Remainder of larvæ—sex undetermined.

TABLE XI.—*Length of feeding period of wintering larvæ of the first brood, watered stock-jar method, Winthrop, Me., 1913.*

[Figures in parentheses ( ) denote sex undetermined.]

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.															
		19		20		21		22		23		24		25		26	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
4	July 7	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
17	July 8	....	....	....	....	....	....	....	....	....	....	1	....	....	....	2	(2)
16	July 9	....	....	....	....	....	....	....	....	....	....	....	1	(1)	....	1	1
11	July 10	....	....	....	....	....	....	....	1	....	1	(2)	1	....	....	1	2
13	July 11	....	....	....	....	....	....	2	....	4	4	....	....	....	2	....	....
26	July 12	....	....	....	....	....	....	....	1	(1)	3	....	....	5	1(1)	4	2
10	July 13	....	....	2	....	1	....	....	....	2	1	....	....	1	....	1	1
12	July 14	....	....	....	....	....	....	....	1	(1)	....	(1)	2	....	2	1	2
19	July 15	1	....	2	....	3	1	....	3	1	....	1	1	....	....	1	3
17	July 16	....	....	....	....	1	....	....	1	....	2	2	1	1	....	1	3
18	July 17	....	....	....	....	....	....	....	....	....	1	1	....	....	....	....	....
9	July 18	....	....	....	....	....	....	....	....	2	....	....	....	1	2	....	1
18	July 20	....	....	....	....	1	....	....	2	....	....	....	2	1	2	....	1
15	July 21	....	....	....	....	....	....	3	....	....	....	....	....	....	....	....	....
8	July 22	....	....	....	....	....	....	2	2	....	1	....	....	....	....	1	1
15	July 23	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	1
15	July 24	....	....	....	....	....	....	....	....	....	....	....	1	....	1	6	1
7	July 25	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	4
7	July 26	....	....	....	....	....	....	....	1	....	1	....	....	1	....	1	....
3	July 27	....	....	....	....	....	....	1	....	1	....	....	....	1	....	....	....
260 ♂ and ♀		1	0	4	0	6	1	8	12	10	14	5	9	11	10	22	23
Sex undetermined		....		....		....		....		2		3		2		2	
Total		1		4		7		20		26		17		23		47	

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.															
		27		28		29		30		31		32		33			
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀		
4	July 7	....	2	....	1	1	....	....	....	....	....	....	....	....	....		
17	July 8	....	....	2	1(2)	....	....	1	2	....	....	....	....	1	1		
16	July 9	....	2	....	3	....	....	1	2	(1)	....	1	....	....	....		
11	July 10	1	1	....	....	....	1	....	....	....	....	....	....	....	....		
13	July 11	(1)	....	....	....	....	....	....	....	....	....	....	....	....	....		
26	July 12	(1)	2	....	....	(1)	3	....	....	....	....	(1)	....	....	....		
10	July 13	....	1	....	....	....	....	....	....	....	....	....	....	....	....		
12	July 14	....	1	1	....	....	....	....	....	....	....	....	....	....	....		
19	July 15	....	....	....	....	....	....	....	....	....	....	1	....	....	1		
17	July 16	....	1	....	1	(1)	1	....	....	1	....	....	....	....	....		
18	July 17	1	....	2	....	....	....	3	....	....	2	2	1	1	....		
9	July 18	....	....	....	....	1	1	....	....	....	1	....	....	....	....		
18	July 20	1	1	....	1	1	1	1	(2)	1	....	....	....	....	....		
15	July 21	3(2)	2	....	2	....	....	....	....	....	....	(1)	2	....	....		
8	July 22	(1)	....	....	....	....	....	....	....	....	....	....	....	....	....		
15	July 23	2	2	1	....	1	1	....	....	2	....	....	....	....	....		
15	July 24	....	....	2	2(1)	....	....	(1)	....	....	....	....	....	....	....		
7	July 25	....	....	....	....	....	1	....	....	....	....	....	1	....	....		
7	July 26	....	....	2	....	....	....	....	....	....	1	....	....	....	....		
3	July 27	....	....	....	....	....	....	....	....	....	....	....	....	....	....		
260 ♂ and ♀		8	15	10	11	4	9	6	4	4	4	4	4	2	2		
Sex undetermined		5		3		2		3		1		2		....			
Total		28		24		15		13		9		10		4			

TABLE XI.—*Length of feeding period of wintering larvæ of the first brood, watered stock-jar method, Winthrop, Me., 1913*—Continued.

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.													
		34		35		36		37		38		40		41	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
4	July 7														
17	July 8			1							1				
16	July 9	1										1			
11	July 10														
13	July 11														
26	July 12														
10	July 13														
12	July 14														
19	July 15														
17	July 16														
18	July 17						1		1		1				1
9	July 18														
18	July 20														
15	July 21														
8	July 22														
15	July 23	2		1								(1)			
15	July 24														
7	July 25														
7	July 26														
3	July 27														
260 ♂ and ♀		3		2			1		1		2	1			1
Sex undetermined												1			
Total		3		2		1		1		2		2		1	

Average length of feeding period, 260 male and female larvæ, 26.569 days; 111 male larvæ, 26.315 days; 123 female larvæ, 26.463 days.

Maximum length of feeding period, 260 male and female larvæ, 41 days; 111 male larvæ, 40 days; 123 female larvæ, 41 days.

Minimum length of feeding period, 260 male and female larvæ, 19 days; 111 male larvæ, 19 days; 123 female larvæ, 20 days.

Length of the feeding period of wintering first-brood larvæ (bagged-fruit method).—Table XII shows that the average feeding period of 236 male and female larvæ was 32.572 days; maximum, 49 days; minimum, 19 days. The average for 93 male larvæ was 29.182 days; maximum, 49 days; minimum, 24 days. The average for 126 female larvæ was 35.492 days; maximum, 46 days; minimum, 19 days. The sex of the remainder of the larvæ was undetermined.

TABLE XII.—*Length of feeding period of wintering larvæ of the first brood, bagged-fruit method, Winthrop, Me., 1913.*

[Figures in parentheses ( ) denote sex undetermined.]

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.																	
		19		23		24		25		26		27		28		29		30	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
1	July 3											1							
17	July 4									2				1		2	3	1	
10	July 5											1	1			1	1		2
11	July 6									1		1	1	1		(1)	2	1	(1)
22	July 7							1		6	4	4	1			(1)	2	2	1
19	July 8						1	1		1	2			3(2)	3				3
29	July 9					1		3	3		2	1	5	2	3			(2)	2
15	July 10				1	3	1(1)	1		1	1		3		1	1			1
12	July 11								1			1			2		2		1
10	July 12										1	1			1			1	1
24	July 13					1	(1)	1	1	2	2(1)		1	2		4	1(1)		
11	July 14								1	1		1	1		1			2	
10	July 15													1	1				
4	July 16																		
15	July 17											1					2		
8	July 20		1										2		1	1			
11	July 22								2	1		2	(1)						
7	July 23							1					1				1		
236 ♂ and ♀			1	0	1	5	2	8	8	15	12	14	16	10	13	9	14	7	11
Sex undetermined						2				1		1		2		3		3	
Total		1		1		9		16		28		31		25		26		21	

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.																	
		31		32		33		34		35		36		37		39			
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀		
1	July 3																		
17	July 4			2		1		1					1		1				
10	July 5		2			(1)											1		
11	July 6	1																	
22	July 7																		
19	July 8	1			2														
29	July 9		1	3											1				
15	July 10																		
12	July 11		2		2					(1)									
10	July 12			1			3						1						
24	July 13			2				1			1		1						
11	July 14			1	2	1													
10	July 15		1		2			1	1		1				1				
4	July 16				1														
15	July 17			1	2						1	1	3	(1)					
8	July 20				1		1							1					
11	July 22	(2)	3																
7	July 23	1									2				1				
236 ♂ and ♀		3	9	10	12	2	4	3	1		5	1	6	1	4		1		
Sex undetermined		2				1				1				1					
Total		14		22		7		4		6		7		6		1			

TABLE XII.—*Length of feeding period of wintering larvæ of the first brood, bagged-fruit method, Winthrop, Me., 1913*—Continued.

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.															
		40		41		42		43		44		46		47		49	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
1	July 3																
17	July 4							2									
10	July 5																
11	July 6				1												
22	July 7																
19	July 8																
29	July 9																
15	July 10																
12	July 11																
10	July 12																
24	July 13	1															
11	July 14																
10	July 15						1										
4	July 16				1		1									1	
15	July 17										1		1	1			
8	July 20																
11	July 22																
7	July 23																
236 ♂ and ♀		1			2		2	2			1		1	1		1	
Sex undetermined																	
Total		1		2		2		2		1		1		1		1	

Average length of feeding period, 236 male and female larvæ, 32.572 days; 93 male larvæ, 29.182 days; 126 female larvæ, 35.492 days.

Maximum length of feeding period, 236 male and female larvæ, 49 days; 93 male larvæ, 49 days; 126 female larvæ, 46 days.

Minimum length of feeding period, 236 male and female larvæ, 19 days; 93 male larvæ, 24 days; 126 female larvæ, 19 days.

It will be noted that the larvæ which transform during the same season as hatched have, upon an average, a shorter feeding period than those which do not transform until the following spring. The average feeding period for 30 transforming larvæ of the first brood was 23.432 days; the average feeding period for 886 wintering larvæ of the first brood was 27.884 days. It will be further noted that in every instance, except one (Table VII), the average feeding period of the female larvæ was longer than that of the male. In the exception cited the result is not considered conclusive, owing to the small number of observations.

Larval life in the cocoon.—The time of making the cocoon is calculated from the time a transforming larva leaves the fruit until it has pupated. The average time consumed in constructing the cocoon was 6.566 days; maximum, 13 days; minimum, 2 days. (See Table XIII.)

TABLE XIII.—*Length of the pupal stage of the first brood, Winthrop, Me., 1913.*

No. of observation.	Date of—			Making of cocoon.	Pupal period.	No. of observation.	Date of—			Making of cocoon.	Pupal period.
	Leaving fruit.	Pupation.	Emergence.				Leaving fruit.	Pupation.	Emergence.		
				Days.	*Days.*					*Days.*	*Days.*
1	July 25	July 30	Aug. 11	5	12	16	July 31	Aug. 6	Aug. 23	6	17
2	July 26	...do....	Aug. 14	4	15	17	...do....	Aug. 8	Aug. 27	8	19
3	July 27	...do....	...do....	3	15	18	...do....	Aug. 9	Aug. 23	9	14
4	...do....	Aug. 1	Aug. 16	5	15	19	Aug. 2	Aug. 8	Aug. 27	6	19
5	July 28	Aug. 3	Aug. 17	6	14	20	...do....	Aug. 9	Aug. 24	7	15
6	July 29	...do....	...do....	5	14	21	Aug. 3	...do....	Aug. 23	6	14
7	...do....	...do....	...do....	5	14	22	...do....	Aug. 10	Aug. 25	7	15
8	July 30	...do....	...do....	4	14	23	...do....	Aug. 11	Aug. 26	8	15
9	...do....	Aug. 4	...do....	5	13	24	...do....	Aug. 15	Aug. 30	12	15
10	...do....	Aug. 5	Aug. 20	6	15	25	...do....	Aug. 16	Sept. 1	13	16
11	...do....	Aug. 7	Aug. 22	8	15	26	Aug. 5	Aug. 11	Aug. 26	6	15
12	...do....	Aug. 9	Aug. 26	10	17	27	Aug. 6	Aug. 13	Aug. 31	7	18
13	July 31	Aug. 4	Aug. 18	4	14	28	Aug. 7	Aug. 14	Aug. 29	7	15
14	...do....	Aug. 5	Aug. 19	5	14	29	Aug. 8	Aug. 10	Aug. 26	2	16
15	...do....	Aug. 6	...do....	6	13	30	Aug. 10	Aug. 22	Sept. 6	12	15
Average										6.566	15.066
Maximum										13	19
Minimum										2	12

FIRST BROOD OF PUPÆ OR SUMMER PUPÆ.

Time of pupation.—The earliest pupation of the first-brood larvæ occurred July 30, the latest August 22. (See Table XIII and fig. 3.)

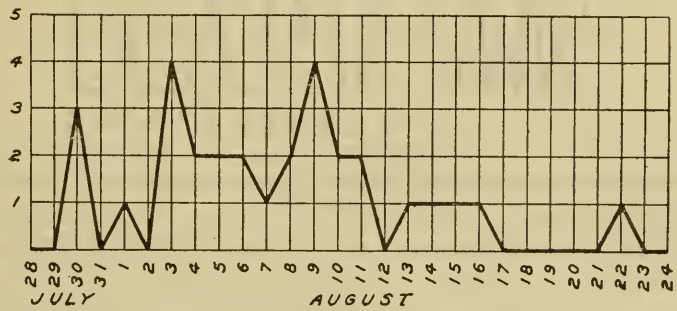

FIG. 3.—Diagram showing pupation of the first brood of the codling moth in 1913 at Winthrop, Me. (Original.)

Length of the pupal stage.—The average length of the first-brood pupal stage, as shown in Table XIII, was 15.066 days; maximum, 19 days; minimum, 12 days.

FIRST OR SUMMER BROOD OF MOTHS.

Time of emergence.—First-brood moth emergence commenced August 7, as shown in Table XIV. The last moth of the summer brood emerged September 6. As previously stated, the number of first-brood larvæ transforming in Maine is comparatively small, and hence the summer brood of moths is small. (See fig. 4.)

TABLE XIV.—*Time of emergence of moths of the first or summer brood, Winthrop, Me., 1913.*

Date of emergence.	Total emergence.	Date of emergence.	Total emergence.
Aug. 7	1	Aug. 23	4
9	3	24	2
11	1	25	1
13	3	26	4
16	1	27	2
17	5	31	2
18	2	Sept. 1	1
19	2	6	1
20	1		
			36

Time of oviposition.—The first eggs of the summer-brood moths were deposited August 15, the last were laid September 25. (See Table XV.)

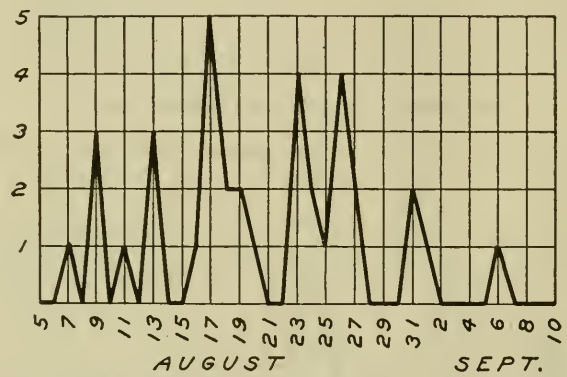

FIG. 4.—Diagram showing emergence of the first brood of moths of the codling moth in 1913 at Winthrop, Me. (Original.)

TABLE XV.—*Time of oviposition of the first or summer brood of moths, Winthrop, Me., 1913.*

CAGE NO. 1.

Date.	Number of moths emerged.	Eggs deposited.	Death of moths.[1]		Date.	Number of moths emerged.	Eggs deposited.	Death of moths.[1]	
			Male.	Female.				Male.	Female.
Aug. 7	1	.....	.....	.....	Aug. 19	.....	Eggs...	1	.....
9	3	.....	.....	.....	20	.....	.....	1	1
11	1	.....	.....	.....	25	.....	.....	1	.....
13	3	.....	.....	.....	26	.....	.....	1	1
15	.....	Eggs...	.....	.....	Sept. 3	.....	.....	.....	1
16	1	...do....	.....	.....					
17	.....	...do....	.....	.....		9		4	4
18	.....	...do....	.....	1					

[1] One moth escaped from cage No. 1, 2 from cage No. 2.

TABLE XV.—*Time of oviposition of the first or summer brood of moths, Winthrop, Me., 1913*—Continued.

CAGE NO. 2.

Date.	Number of moths emerged.	Eggs deposited.	Death of moths.		Date.	Number of moths emerged.	Eggs deposited.	Death of moths.	
			Male.	Female.				Male.	Female.
Aug. 17	5	.....	.....	.....	Sept. 4	.....	Eggs...	2	1
18	2	.....	.....	.....	5	.....	...do....	.....	.....
19	2	.....	.....	.....	6	1	...do....	.....	.....
20	1	.....	.....	.....	7	.....	...do....	.....	2
21	.....	.....	.....	.....	8	.....	...do....	.....	.....
22	.....	Eggs...	.....	.....	10	.....	...do....	.....	2
23	4	...do....	.....	.....	12	.....	...do....	.....	1
24	2	...do....	.....	1	14	.....	.....	1	1
25	1	...do....	.....	.....	15	.....	Eggs...	.....	.....
26	4	...do....	.....	1	20	.....	.....	1	.....
27	2	...do....	.....	.....	22	.....	Eggs...	.....	.....
28	.....	...do....	.....	.....	25	.....	...do....	.....	.....
29	.....	...do....	.....	.....	26	.....	.....	1	.....
30	.....	...do....	.....	2	27	.....	.....	1	1
31	2	...do....	2	1	28	.....	.....	1	.....
Sept. 1	1	...do....	1	2					
2	.....	...do....	.....	.....		27		10	15
3	.....	...do....	.....	.....					

Number of eggs per first-brood female moth.—This data was obtained by dividing the total number of second-brood eggs (1,013) by the total number of female moths kept in confinement. These figures show that the average number of eggs per female was 53.316.

LENGTH OF LIFE CYCLE OF THE FIRST GENERATION.

In view of the fact that three methods of taking codling-moth feeding records were used, it became necessary to give the life-cycle results in three separate tables—Tables XVI, XVII, and XVIII. These tables include the life cycle of the insect from the time of egg deposition to the emergence of the moth and, as recorded therein, the life cycle according to the stock-jar method was 47.818 days; watered stock-jar method, 53.500 days; bagged-fruit method, 54 days. The complete life cycle extends from the time of the deposition of the egg of one generation to the deposition of the egg of the next generation. Hence, in order to get the number of days for the complete life cycle the time elapsing from the emergence of the moth to the first oviposition—approximately 4 days—should be added to the above figures.

TABLE XVI.—*Life cycle of the first generation of the codling moth, as observed by rearing at Winthrop, Me., 1913, stock-jar feeding method.*

No. of observation.	Date of—					Days for—				
	Egg deposition.	Hatching.	Larva leaving the fruit.	Pupation.	Emergence of moth.	Hatching.	Feeding.	Making of cocoon.	Pupal period.	Life cycle.[1]
1	June 30	July 6	July 30 ♂	Aug. 7	Aug. 22	6	24	8	15	53
2	July 1	July 7	July 25	July 30	Aug. 11	6	18	5	12	41
3	...do	...do	July 26	...do	Aug. 14	6	19	4	15	44
4	...do	...do	July 27	Aug. 1	Aug. 16	6	20	5	15	46
5	...do	...do	July 28 ♂	Aug. 3	Aug. 17	6	21	6	14	47
6	...do	...do	July 29 ♂	...do	...do	6	22	5	14	47
7	...do	...do	July 31 ♀	Aug. 6	Aug. 19	6	24	6	13	49
8	July 3	July 10	July 30 ♀	Aug. 5	Aug. 20	7	20	6	15	48
9	...do	...do	July 31 ♀	Aug. 9	Aug. 23	7	21	9	14	51
10	July 7	July 15	Aug. 3 ♀	Aug. 15	Aug. 30	8	19	12	15	54
11	July 11	July 19	Aug. 5 ♀	Aug. 11	Aug. 26	8	17	6	15	46
Average						6.545	20.454	6.545	14.272	47.818
Maximum						8	24	12	15	54
Minimum						6	17	4	12	41

[1] Add 4 days for complete life cycle.

TABLE XVII.—*Life cycle of the first generation of the codling moth, as observed by rearing at Winthrop, Me., 1913, watered stock-jar feeding method.*

No. of observation.	Date of—					Days for—				
	Egg deposition.	Hatching.	Larva leaving the fruit.	Pupation.	Emergence of moth.	Hatching.	Feeding.	Making of cocoon.	Pupal period.	Life cycle.[1]
1	July 1	July 7	July 29[2]	Aug. 3	Aug. 17	6	22	5	14	47
2	...do	...do	July 30[2]	...do	...do	6	23	4	14	47
3	July 2	July 8	Aug. 3[3]	Aug. 9	Aug. 23	6	26	6	14	52
4	...do	...do	Aug. 8	Aug. 10	Aug. 26	6	31	2	16	55
5	July 3	July 10	Aug. 6[2]	Aug. 13	Aug. 31	7	27	7	18	59
6	July 4	July 11	Aug. 3[3]	Aug. 16	Sept. 1	7	23	13	16	59
7	July 5	July 12	Aug. 2[2]	Aug. 9	Aug. 24	7	21	7	15	50
8	...do	...do	Aug. 3[2]	Aug. 10	Aug. 25	7	22	7	15	51
9	...do	...do	Aug. 7[3]	Aug. 14	Aug. 29	7	26	7	15	55
10	July 8	July 16	Aug. 10[3]	Aug. 22	Sept. 6	8	25	12	15	60
Average						6.7	24.6	7	15.2	53.5
Maximum						8	31	13	18	60
Minimum						6	21	2	14	47

[1] Add 4 days for complete life cycle. [2] Male. [3] Female.

TABLE XVIII.—*Life cycle of the first generation of the codling moth, as observed by rearing at Winthrop, Me., 1913, bagged-fruit feeding method.*

No. of observation.	Date of—					Days for—				
	Egg deposition.	Hatching.	Larva leaving the fruit.	Pupation.	Emergence of moth.	Hatching.	Feeding.	Making of cocoon.	Pupal period.	Life cycle.[1]
1	June 26	July 3	July 27	July 30	Aug. 14	7	24	3	15	49
2	June 28	July 4	July 30[2]	Aug. 9	Aug. 26	6	26	10	17	59
3	...do....	...do....	July 31[2]	Aug. 8	Aug. 27	6	27	8	19	60
4	...do....	...do....	...do.[3]..	Aug. 6	Aug. 23	6	27	6	17	56
5	...do....	...do....	Aug. 3[2]	Aug. 11	Aug. 26	6	30	8	15	59
6	June 29	July 5	July 30[1]	Aug. 4	Aug. 17	6	25	5	13	49
7	...do....	...do....	Aug. 2[2]	Aug. 8	Aug. 27	6	28	6	19	59
8	July 1	July 7	July 31[3]	Aug. 4	Aug. 18	6	24	4	14	48
9	July 3	July 10	...do.[3]..	Aug. 5	Aug. 19	7	21	5	14	47
Average						6.222	25.777	6.111	15.888	54
Maximum						7	30	10	19	60
Minimum						6	21	3	13	47

[1] Add 4 days for complete life cycle. [2] Male. [3] Female.

As shown in Table XIX, which is a summary of Tables XVI, XVII, and XVIII, the average of the life cycles was 51.566 days. The complete life cycle would be about 55 to 56 days.

TABLE XIX.—*Summary of the life cycle of the first generation of the codling moth, Winthrop, Me., 1913.*

	Number of observations.	Larval feeding method.	Days for—				
			Hatching.	Feeding.	Making of cocoon.	Pupal period.	Life cycle.[1]
Average life cycle	11	A	6.545	20.454	6.545	14.272	47.818
Do	10	B	6.700	24.600	7.000	15.200	53.500
Do	9	C	6.222	25.777	6.111	15.888	54.000
Average of all life cycles	30	A+B+C	6.499	23.432	6.566	15.066	51.566

[1] Add 4 days for complete life cycle.
A, stock-jar method; B, watered stock-jar method; C, bagged-fruit method.

THE SECOND GENERATION.

SECOND BROOD OF EGGS.

Length of incubation.—Observations on the period of incubation extended from August 15, when the first eggs of the second brood were deposited, until October 15, when the last of the eggs of this brood hatched. A total of 1,013 eggs were laid, of which number 972 (95.9 per cent) hatched. The average incubation period was 11.862 days; maximum, 23 days; minimum, 7 days. The average time for the appearance of the red ring was 2.884 days; maximum, 7 days; minimum, 1 day. The average time for the appearance of the black spot was 9.069 days; maximum, 18 days; minimum, 5 days. The incubation observations are recorded in Table XX.

TABLE XX.—*Length of incubation of second brood of eggs, Winthrop, Me., 1913.*

No. of observation.	Number of eggs.	Date—				Appearance of—		Incubation period.	Number dead.
		Deposited.	Red ring.	Black spot.	Hatched.	Red ring.	Black spot.		
						Days.	*Days.*	*Days.*	
1	10	Aug. 15	Aug. 16	Aug. 21	Aug. 23	1	6	8	2
2	28	Aug. 16	Aug. 17	Aug. 22	Aug. 24	1	6	8	.....
3	10	...do.....	.....	.....	Aug. 25	.....	.....	9	.....
4	15	Aug. 17	Aug. 19	Aug. 24	...do.....	2	7	8	.....
5	48	...do.....	.....	.....	Aug. 26	.....	.....	9	14
6	17	Aug. 18	Aug. 20	Aug. 25	Aug. 27	2	7	9	.....
7	31	...do.....	.....	.....	Aug. 28	.....	.....	10	.....
8	10	...do.....	.....	.....	Aug. 29	.....	.....	11	2
9	7	Aug. 19	Aug. 22	Aug. 26	...do.....	3	7	10	.....
10	2	...do.....	.....	.....	Aug. 30	.....	.....	11	1
11	5	Aug. 22	Aug. 25	Aug. 30	Sept. 1	3	8	10	.....
12	86	Aug. 23	.....	...do.....	...do.....	2	7	9	.....
13	3	...do.....	.....	.....	Sept. 2	.....	.....	10	.....
14	26	Aug. 24	Aug. 27	Sept. 1	...do.....	3	8	9	.....
15	8	...do.....	.....	.....	Sept. 3	.....	.....	10	.....
16	1	Aug. 25	Aug. 28	Sept. 1	Sept. 2	3	7	8	.....
17	3	...do.....	.....	.....	Sept. 3	.....	.....	9	.....
18	16	Aug. 26	Aug. 29	Sept. 1	...do.....	3	6	8	.....
19	16	Aug. 27	Aug. 31	Sept. 2	...do.....	4	6	7	.....
20	42	...do.....	.....	.....	Sept. 4	.....	.....	8	5
21	36	Aug. 28	Aug. 31	Sept. 3	...do.....	3	6	7	.....
22	9	...do.....	.....	.....	Sept. 5	.....	.....	8	1
23	.....	.....	.....	.....	.....	.....	.....	.....	.....
24	5	Aug. 30	Sept. 2	Sept. 4	Sept. 6	3	5	7	.....
25	28	...do.....	.....	.....	Sept. 7	.....	.....	8	.....
26	4	...do.....	.....	.....	Sept. 8	.....	.....	9	.....
27	61	Aug. 31	Sept. 3	Sept. 6	...do.....	3	6	8	.....
28	9	...do.....	.....	.....	Sept. 9	.....	.....	9	.....
29	22	...do.....	.....	.....	Sept. 10	.....	.....	10	1
30	30	Sept. 1	Sept. 3	Sept. 8	...do.....	2	7	9	.....
31	15	...do.....	.....	.....	Sept. 11	.....	.....	10	.....
32	12	...do.....	.....	.....	Sept. 12	.....	.....	11	5
33	31	Sept. 2	Sept. 4	Sept. 10	Sept. 14	2	8	12	.....
34	15	...do.....	.....	.....	Sept. 15	.....	.....	13	.....
35	11	...do.....	.....	.....	Sept. 16	.....	.....	14	2
36	109	Sept. 3	Sept. 6	Sept. 15	Sept. 18	3	12	15	.....
37	16	...do.....	.....	.....	Sept. 19	.....	.....	16	.....
38	1	...do.....	.....	.....	Sept. 20	.....	.....	17	.....
39	4	...do.....	.....	.....	Sept. 21	.....	.....	18	3
40	24	Sept. 4	Sept. 7	Sept. 17	...do.....	3	13	17	.....
41	2	...do.....	.....	.....	Sept. 22	.....	.....	18	.....
42	48	Sept. 5	Sept. 8	Sept. 18	...do.....	3	13	17	.....
43	16	...do.....	.....	.....	Sept. 23	.....	.....	18	.....
44	5	...do.....	.....	.....	Sept. 24	.....	.....	19	.....
45	6	Sept. 6	Sept. 10	Sept. 22	...do.....	4	16	18	.....
46	2	...do.....	.....	.....	Sept. 25	.....	.....	19	.....
47	27	Sept. 7	Sept. 12	Sept. 23	Sept. 26	5	16	19	.....
48	3	...do.....	.....	.....	Sept. 27	.....	.....	20	.....
49	32	Sept. 8	Sept. 13	Sept. 26	Sept. 29	5	18	21	.....
50	7	...do.....	.....	.....	Sept. 30	.....	.....	22	5
51	8	Sept. 10	Sept. 17	Sept. 28	Oct. 2	7	18	22	.....
52	2	...do.....	.....	.....	Oct. 3	.....	.....	23	.....
53	4	Sept. 12	Sept. 18	Sept. 29	...do.....	6	17	21	.....
54	1	...do.....	.....	.....	Oct. 4	.....	.....	22	.....
55	8	Sept. 15	Sept. 20	Sept. 30	...do.....	5	15	19	.....
56	4	Sept. 22	Sept. 26	Oct. 6	Oct. 8	4	14	16	.....
57	4	...do.....	.....	.....	Oct. 9	.....	.....	17	.....
58	2	...do.....	.....	.....	Oct. 10	.....	.....	18	.....
59	6	Sept. 25	Oct. 1	Oct. 10	Oct. 15	6	15	20	.....
Average						2.884	9.069	11.862	41
Maximum						7	18	23	.....
Minimum						1	5	7	.....

SECOND BROOD OF LARVÆ.

Time of hatching.—By reference to Table XX it will be noted that second-brood codling-moth eggs were hatching from August 23 to October 15. Hence the larvæ were hatching over a period of nearly two months.

Length of feeding period.—Observations on the feeding period of the second-brood larvæ are given in Table XXI. Although hatching continued until October 15, none of the larvæ which entered the fruit later than September 11 matured. The first of the second-brood larvæ left the fruit September 25, the last November 21. The average feeding period for all larvæ was 49.160 days; maximum, 77 days; minimum, 31 days. The average feeding period for 47 male larvæ was 46.659 days; maximum, 77 days; minimum, 31 days. The average feeding period for 57 female larvæ was 50.245 days; maximum, 72 days; minimum, 33 days. It will again be noted that the feeding period of female larvæ is longer than that of the male.

TABLE XXI.—*Length of feeding period of second-brood larvæ, stock-jar method, Winthrop, Me., 1913.*

[Figures in parentheses ( ) denote sex undetermined.]

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.																	
		31		33		34		36		37		38		39		40		41	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
3	Aug. 23	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	1
3	Aug. 24	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	1	....	....
9	Aug. 25	1	....	....	....	....	....	....	....	1	....	....	1	....	1	....	....	....	1
7	Aug. 26	....	....	1	1	....	....	....	....	....	....	....	1	....	....	....	1	1	....
8	Aug. 27	....	....	....	....	....	....	2	....	....	....	1	1	1	....	....	1	....	....
10	Aug. 28	....	....	....	....	....	....	1	....	1	....	3	1	1	1	....	....	....	....
3	Aug. 29	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....
1	Aug. 30	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
20	Sept. 1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
13	Sept. 2	....	....	....	....	....	....	....	....	....	....	....	....	1	2	1	....	....	....
2	Sept. 3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
11	Sept. 4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
2	Sept. 5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
5	Sept. 6	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
5	Sept. 8	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
2	Sept. 9	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
2	Sept. 11	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
106 ♂ and ♀.		1	0	1	1	1	0	3	0	2	0	4	4	3	4	2	4	1	2
Sex undetermined.		.....		.....		.....		.....		.....		.....		.....		.....		.....	
Total.....		1		2		1		3		2		8		7		6		3	

TABLE XXI.—*Length of feeding period of second-brood larvæ, stock-jar method, Winthrop, Me., 1913*—Continued.

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.																	
		42		43		44		45		46		47		48		49		50	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
3	Aug. 23	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....
3	Aug. 24	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
9	Aug. 25	....	....	1	1	....	....	....	1	....	....	....	....	....	....	1	....	....	....
7	Aug. 26	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....
8	Aug. 27	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1
10	Aug. 28	....	....	1	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....
3	Aug. 29	....	....	....	1	....	....	....	....	....	....	1	....	....	....	....	....	....	....
1	Aug. 30	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....
20	Sept. 1	1	....	....	....	3	....	....	2	....	1	....	....	1	2	....	....	....	2
13	Sept. 2	....	....	1	....	1	....	1	....	....	1	....	1	....	....	....	....	....	....
2	Sept. 3	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....
11	Sept. 4	....	....	....	....	....	....	1	....	....	....	1	....	....	....	....	....	....	....
2	Sept. 5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
5	Sept. 6	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
5	Sept. 8	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
2	Sept. 9	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1
2	Sept. 11	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
106 ♂ and ♀.		1	0	3	2	5	1	2	3	0	3	2	1	1	3	1	1	0	4
Sex undetermined.		.....		.....		.....		.....		.....		.....		.....		.....		.....	
Total.....		1		5		6		5		3		3		4		2		4	

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.																	
		51		52		53		54		55		56		58		61		62	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
3	Aug. 23	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
3	Aug. 24	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
9	Aug. 25	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
7	Aug. 26	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
8	Aug. 27	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....
10	Aug. 28	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
3	Aug. 29	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1	Aug. 30	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
20	Sept. 1	....	....	....	....	....	....	2	2	....	....	2	1	....	1	....	....	....	....
13	Sept. 2	....	....	....	....	....	3	....	....	....	1	....	....	....	....	....	....	....	....
2	Sept. 3	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....
11	Sept. 4	....	2	....	....	2	1	....	....	....	....	....	....	....	....	....	....	....	....
2	Sept. 5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
5	Sept. 6	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1
5	Sept. 8	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
2	Sept. 9	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
2	Sept. 11	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....
106 ♂ and ♀.		0	3	1	1	2	4	2	2	0	1	2	1	0	1	2	0	0	1
Sex undetermined.		.....		.....		.....		.....		.....		.....		.....		.....		.....	
Total.....		3		2		6		4		1		3		1		2		1	

TABLE XXI.—*Length of feeding period of second-brood larvæ, stock-jar method, Winthrop, Me., 1913*—Continued.

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.																	
		64		65		66		69		70		71		72		75		77	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
3	Aug. 23	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
3	Aug. 24	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....
9	Aug. 25	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
7	Aug. 26	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....
8	Aug. 27	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
10	Aug. 28	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
3	Aug. 29	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1	Aug. 30	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
20	Sept. 1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
13	Sept. 2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
2	Sept. 3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
11	Sept. 4	....	1	....	....	....	1	....	....	....	....	....	....	....	....	....	....	(2)	....
2	Sept. 5	....	....	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....
5	Sept. 6	1	1	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....
5	Sept. 8	....	....	....	....	....	....	....	....	1	3	....	....	....	....	....	....	....	....
2	Sept. 9	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....
2	Sept. 11	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....
106 ♂ and ♀.		1	2	1	1	0	1	0	1	1	3	0	1	0	1	1	0	1	0
Sex undetermined.		.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2	
Total.....		3		2		1		1		4		1		1		1		3	

Average length of feeding period, 106 male and female larvæ, 49.160 days; 47 male larvæ, 46.659 days; 57 female larvæ, 50.245 days.

Maximum length of feeding period, 106 male and female larvæ, 77 days; 47 male larvæ, 77 days; 57 female larvæ, 72 days.

Minimum length of feeding period, 106 male and female larvæ, 31 days; 47 male larvæ, 31 days; 57 female larvæ, 33 days.

BAND RECORD EXPERIMENT, 1913–14.

As previously stated, the collecting of codling-moth larvæ from banded trees serves as a basis for comparison of the larvæ living under natural conditions with those reared under laboratory conditions. As shown in Table XXII, the first larvæ left the fruit of the banded trees July 21, while the last were collected October 13. The first of the larvæ reared at the insectary left the fruit July 25.

Out of a total of 1,012 larvæ collected from the bands, but 8 larvæ (less than 1 per cent) transformed during 1913. One parasite (*Ascogaster carpocapsæ* Vier.) emerged in 1913.

Owing to the exceptionally severe winter of 1913–14 the mortality of the wintering larvæ was very high. It was computed that 81.52 per cent of the larvæ were killed, due to the low temperatures.

In the spring of 1914, 82 moths and 96 parasites emerged. The parasites were all of the species *Ascogaster carpocapsæ* Vier.

The well known codling-moth enemy *Tenebroides corticalis* Melsh. was frequently found attacking the larvæ beneath the bands.

TABLE XXII.—*Band record experiment, Winthrop, Me., 1913–14.*

No. of record.	Date of collecting.	Number of larvæ.	Number of moths, 1913.	Number of parasites, 1913.	Number of moths, 1914.	Number of parasites, 1914.	Total number dead larvæ.
1	July 21	2	2	.....	.....	.....	0
2	July 24	3	3	.....	.....	.....	0
3	July 27	4	2	1	.....	.....	1
4	July 30	5	1	.....	.....	.....	4
5	Aug. 2	11	.....	.....	1	.....	10
6	Aug. 5	5	.....	.....	.....	1	4
7	Aug. 8	4	.....	.....	2	2	0
8	Aug. 11	15	.....	.....	2	2	11
9	Aug. 14	25	.....	.....	2	4	19
10	Aug. 17	46	.....	.....	3	5	38
11	Aug. 20	92	.....	.....	8	10	74
12	Aug. 23	102	.....	.....	6	13	83
13	Aug. 26	70	.....	.....	1	14	55
14	Aug. 29	78	.....	.....	5	8	65
15	Sept. 1	94	.....	.....	3	8	85
16	Sept. 4	123	.....	.....	5	11	107
17	Sept. 7	77	.....	.....	6	7	64
18	Sept. 10	51	.....	.....	7	5	39
19	Sept. 13	38	.....	.....	10	1	27
20	Sept. 16	26	.....	.....	5	4	17
21	Sept. 19	27	.....	.....	4	1	22
22	Sept. 22	13	.....	.....	2	0	11
23	Sept. 25	30	.....	.....	2	.....	28
24	Sept. 28	13	.....	.....	3	.....	10
25	Oct. 1	22	.....	.....	2	.....	20
26	Oct. 4	10	.....	.....	1	.....	9
27	Oct. 7	11	.....	.....	1	.....	10
28	Oct. 10	9	.....	.....	1	.....	8
29	Oct. 13	6	.....	.....	0	.....	6
Total.....		1,012	8	1	82	96	825

Parasites, *Ascogaster carpocapsæ* Vier.

SEASONAL-HISTORY STUDIES OF 1914.

The life-history studies of the codling moth which were commenced in 1913 were continued during the season of 1914. Although the notes secured in 1913 were complete in themselves, it was considered desirable to extend the observations over a period of at least two seasons, in order to note any differences in the behavior of the insect due to climatic variations. All of the explanations and descriptions of the methods used in the studies of 1913 are applicable to the investigations of 1914.

SOURCE OF REARING MATERIAL.

The overwintering larvæ consisted of the larvæ which were reared under laboratory conditions and the larvæ collected from the banded trees, as well as miscellaneous larvæ which were secured from wormy apples. The miscellaneous larvæ passed the winter in corrugated paper strips, while the remainder of the larvæ wintered in the "cocoon racks." The larvæ were kept under normal outdoor conditions throughout the winter.

WINTER-KILLED LARVÆ.

Owing to the low temperatures during the winter of 1913–14 a high mortality of the codling-moth larvæ occurred. The number of larvæ from the banded trees killed by the winter temperatures is estimated at 81.52 per cent. The number of winter-killed larvæ which had been reared under laboratory conditions was 86.61 per cent. The United States Weather Bureau, Climatological Report for the New England section, January, 1914, makes special mention of the cold wave on January 13 and 14. This report states that "at

FIG. 5.—Diagram showing pupation of the spring brood of the codling moth in 1914 at Winthrop, Me. (Original.)

many stations of long record all previous minimum temperatures were exceeded on these dates."

SPRING BROOD OF PUPÆ.

Time of pupation.—The first of the spring-brood larvæ pupated May 20, the last July 6. (See fig. 5.) Maximum pupation occurred on June 12, when 20 larvæ pupated. In the preceding year the maximum pupation took place on June 6. (See Table XXIII for the time of pupation.)

TABLE XXIII.—*Time of pupation of overwintering larvæ, Winthrop, Me., 1914.*

Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.	Date of pupation.	Number of pupæ.
May 20	1	June 3	8	June 13	18	June 23	6
May 25	1	June 4	3	June 14	14	June 24	6
May 26	1	June 6	2	June 15	4	June 25	10
May 28	1	June 7	9	June 16	4	June 26	1
May 29	4	June 8	4	June 17	3	June 28	4
May 30	3	June 9	6	June 18	5	July 1	1
May 31	3	June 10	15	June 20	2	July 5	1
June 1	1	June 11	16	June 21	4	July 6	2
June 2	3	June 12	20	June 22	11	Total..	197

Length of the pupal stage.—In Table XXIV the length of the pupal stage of 196 spring-brood pupæ is given. The average length of the pupal stage was 22.581 days; maximum, 44 days; minimum, 11 days.

TABLE XXIV.—*Length of pupal stage of spring-brood pupæ, Winthrop, Me., 1914.*

Number of individuals.	Date of pupation.	Length of pupal stage in specified days.																							
		11	12	14	15	16	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	35	43	44
1	May 25								1																
1	May 26										1														
1	May 28													1											
4	May 29											1	1	2											
3	May 30										1		1		1										
3	May 31											1	2												
1	June 1															1									
3	June 2									1	1	1													
8	June 3				1				1	3	1	2													
3	June 4										2													1	
2	June 6								1		1														
9	June 7							1	2	3		2							1						
4	June 8							3			1														
6	June 9									1			2			1	1	1							
15	June 10									2		8	2	1		1									1
16	June 11								2		1	4	5	2	1						1				
20	June 12		1	1						1		3	8	3	1				1			1			
18	June 13								1			2	9	2		2	1		1						
14	June 14					1						5	3	2					1	1			1		
4	June 15											1	2	1											
4	June 16										2		2												
3	June 17											2	1												
5	June 18							1		1		2				1									
2	June 20				1								1												
4	June 21								1	3															
11	June 22			1	1				5	4															
6	June 23							1	2	2	1														
6	June 24							1	2	2		1													
10	June 25					1	1	2	3	2	1														
1	June 26	1																							
4	June 28			1		3																			
1	July 1					1																			
1	July 5					1																			
2	July 6		1		1																				
196 pupæ.....		1	2	3	4	7	1	9	21	24	13	35	40	14	3	6	2	1	4	1	1	1	1	1	1

Average length of the pupal stage, 22.581 days.
Maximum length of the pupal stage, 44 days.
Minimum length of the pupal stage, 11 days.

SPRING BROOD OF MOTHS.

Time of emergence of moths.—In Table XXV is shown the emergence record of 210 spring-brood moths. On June 14 moth emergence commenced and continued until July 19. The maximum emergence occurred July 7, on which date 28 moths appeared. In 1913 the time of moth emergence extended from June 18 to July 20. In 1914 the date of full bloom (Baldwin) was the same as in 1913, namely, May 28.

TABLE XXV.—*Time of emergence of moths of spring brood, Winthrop, Me., 1914. (See fig. 6.)*

Date.	Total.	Date.	Total.	Date.	Total.
June 14	1	July 1	2	July 13	12
June 18	2	July 3	12	July 14	9
June 21	3	July 4	10	July 15	8
June 22	3	July 5	13	July 16	3
June 23	2	July 6	17	July 17	6
June 24	7	July 7	28	July 18	1
June 25	3	July 8	15	July 19	2
June 26	7	July 9	5		
June 27	6	July 10	3		210
June 28	6	July 11	7		
June 30	5	July 12	12		

Time of egg deposition.—The time of egg deposition by moths of the spring brood extended from June 24 to August 5. The average

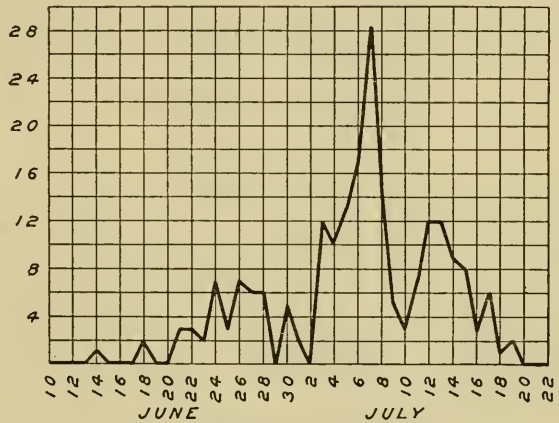

FIG. 6.—Diagram showing emergence of the spring brood of moths of the codling moth in 1914 at Winthrop, Me. (Original.)

number of days from the time of the emergence of moth to first oviposition was 3.272 days; maximum, 7 days; minimum, 2 days. The average number of days of oviposition was 13.636; maximum, 23 days; minimum, 7 days. The average number of days from the time of the emergence of the moth to the end of oviposition was 16 days; maximum, 24 days; minimum, 9 days. (See Table XXVI.)

TABLE XXVI.—*Oviposition by moths of spring brood in rearing cages, Winthrop, Me., 1914.*

Cage.	Number of moths.	Sex. ♀	Sex. ♂	Date of— Emergence.	Date of— First oviposition.	Date of— Last oviposition.	Number of days— Before oviposition.	Number of days— Duration of oviposition.	Number of days— From emergence to end of oviposition.
[1] 1	1	2	1	June 14	June 25	June 26	.....	.....	.....
	2			June 18					
2	3	1	2	June 21	June 24	July 1	3	8	11
[1] 3	3	4	10	June 22	July 1	July 11	.....	.....	.....
	2			June 23					
	6			June 24					
	3			June 25					
[1] 4	7	6	13	June 26	July 4	July 18	.....	.....	.....
	6			June 27					
	6			June 28					
[1] 5	5	2	5	June 30	July 5	July 16	.....	.....	.....
	2			July 1					
6	12	6	6	July 3	July 8	July 14	5	7	11
7	10	3	7	July 4	July 11	July 20	7	10	16
8	13	7	6	July 5	July 8	...do	3	13	15
9	17	6	11	July 6	...do	July 30	2	23	24
10	28	13	15	July 7	July 9	...do	2	22	23
11	14	7	7	July 8	July 11	July 25	3	15	17
[1] 12	5	2	6	July 9	July 14	July 16	.....	.....	.....
	3			July 10					
13	7	4	3	July 11	...do	July 20	3	7	9
14	12	5	7	July 12	July 15	July 25	3	11	13
15	9	4	5	July 14	July 17	Aug. 3	3	18	20
[1] 16	8	9	11	July 15	July 18	Aug. 5	.....	.....	.....
	3			July 16					
	6			July 17					
	1			July 18					
	2			July 19					
17	12	7	5	July 13	July 15	July 30	2	16	17
Number of male moths..... 88					Average.....		3.272	13.636	16
Number of female moths..... 120					Maximum.....		7	23	24
Total number of moths 208					Minimum.....		2	7	9
Total number of eggs..... 2,907									

[1] Not used in the averages.

Number of eggs per female.—As recorded in Table XXVI, 120 female moths confined in cages with male moths deposited a total of 2,907 eggs. From these data the average number of eggs per female was found to be 24.225.

Length of life of moths.—In Table XXVII will be found the length of the life of 72 male and 66 female moths of the spring brood. The average life of the male moth was 13.708 days; of the female, 13.621 days. The maximum life of the male moth was 32 days; of the female, 28 days. The minimum life of the male moth was 2 days; of the female, 1 day.

TABLE XXVII.—*Length of life of male and female moths of spring brood in captivity. Summary of records of 138 individual moths, Winthrop, Me., 1914.*

Male.		Female.		Male.		Female.	
Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.	Length of life.	Number of moths.
Days.		*Days.*		*Days.*		*Days.*	
2	1	1	2	17	6	17	4
3	1	5	1	18	3	18	4
6	3	6	6	19	5	20	2
7	3	7	2	20	3	21	2
8	1	8	3	21	1	22	2
9	9	9	2	22	1	24	1
10	7	10	4	23	1	25	1
11	3	11	2	24	1	27	1
12	5	12	3	27	1	28	2
13	5	13	10	32	1		
14	4	14	7				
15	2	15	4		72		66
16	5	16	1				

Average length of life of male moths, 13.708 days; female moths, 13.621 days.
Maximum length of life of male moths, 32 days; female moths, 28 days.
Minimum length of life of male moths, 2 days; female moths, 1 day.

THE FIRST GENERATION.

FIRST BROOD OF EGGS.

Length of incubation.—Observations of the embryological changes and incubation periods of 2,672 eggs are recorded in Table XXVIII. Of this number, 2,633 (98.54 per cent) hatched. The average number of days from the time of oviposition to the appearance of the red ring was 2.599; maximum, 5 days; minimum, 2 days. The average number of days from the time of oviposition to the appearance of the black spot was 6.139; maximum, 10 days; minimum, 5 days. The average incubation period was 7.797 days; maximum, 13 days; minimum, 6 days.

TABLE XXVIII.—*Length of incubation of first-brood eggs, Winthrop, Me., 1914.*

No. of observation.	Number of eggs.	Date— Deposited.	Red ring.	Black spot.	Hatched.	Appearance of— Red ring.	Black spot.	Incubation period.	Number dead.
						Days.	*Days.*	*Days.*	
1	4	June 24	June 27	July 4	July 6	3	10	12	1
2	3	June 25	June 28	...do....	July 7	3	9	12	.....
3	15	...do.....	.....	.....	July 8	.....	.....	13	1
4	4	June 26	June 30	July 5	...do.....	4	9	12	.....
5	2	June 27	July 2	July 7	...do.....	5	10	11	.....
6	43	July 1	July 4	July 8	July 10	3	7	9	.....
7	7	...do.....	.....	.....	July 11	.....	.....	10	.....
8	18	July 3	July 5	July 9	July 10	2	6	7	.....
9	2	...do.....	.....	.....	July 11	.....	.....	8	.....
10	6	July 4	July 6	July 11	July 12	2	7	8	.....
11	2	...do.....	.....	.....	July 13	.....	.....	9	.....
12	92	July 5	July 7	July 12	...do.....	2	7	8	.....
13	22	...do.....	.....	.....	July 14	.....	.....	9	7
14	29	July 6	July 8	July 13	...do.....	2	7	8	.....
15	12	...do.....	.....	.....	July 15	.....	.....	9	.....
16	132	July 8	July 11	July 14	...do.....	3	6	7	.....
17	84	...do.....	.....	.....	July 16	.....	.....	8	5
18	19	July 9	July 12	July 15	...do.....	3	6	7	.....
19	9	...do.....	.....	.....	July 17	.....	.....	8	.....
20	115	July 10	July 13	July 16	...do.....	3	6	7	.....
21	27	...do.....	.....	.....	July 18	.....	.....	8	4
22	102	July 11	July 13	July 16	July 17	2	5	6	.....
23	20	...do.....	.....	.....	July 18	.....	.....	7	.....
24	110	July 12	July 14	July 17	...do.....	2	5	6	.....
25	160	...do.....	.....	.....	July 19	.....	.....	7	.....
26	21	...do.....	.....	.....	July 20	.....	.....	8	.....
27	101	July 13	July 15	July 18	...do.....	2	5	7	.....
28	17	...do.....	.....	.....	July 21	.....	.....	8	2
29	106	July 14	July 16	July 20	...do.....	2	6	7	.....
30	12	...do.....	.....	.....	July 22	.....	.....	8	.....
31	70	July 15	July 17	July 21	...do.....	2	6	7	.....
32	60	...do.....	.....	.....	July 23	.....	.....	8	.....
33	142	July 16	July 18	July 22	...do.....	2	6	7	.....
34	27	...do.....	.....	.....	July 24	.....	.....	8	7
35	187	July 17	July 20	July 23	...do.....	3	6	7	.....
36	52	...do.....	.....	.....	July 25	.....	.....	8	8
37	42	July 18	July 21	July 24	July 26	3	6	8	.....
38	90	...do.....	.....	.....	July 27	.....	.....	9	3
39	17	July 19	July 22	July 25	...do.....	3	6	8	.....
40	12	...do.....	.....	.....	July 28	.....	.....	9	.....
41	63	July 20	July 23	July 26	...do.....	3	6	8	.....
42	28	...do.....	.....	.....	July 29	.....	.....	9	.....
43	33	July 21	July 24	July 28	July 30	3	7	9	.....
44	9	...do.....	.....	.....	July 31	.....	.....	10	.....
45	38	July 22	July 25	July 29	...do.....	3	7	9	.....
46	17	...do.....	.....	.....	Aug. 1	.....	.....	10	.....
47	16	July 23	July 26	July 30	...do.....	3	7	9	.....
48	6	...do.....	.....	.....	Aug. 2	.....	.....	10	.....
49	57	July 24	July 27	July 31	...do.....	3	7	8	.....
50	9	...do.....	.....	.....	Aug. 3	.....	.....	9	.....
51	106	July 25	July 28	Aug. 1	...do.....	3	7	9	.....
52	70	...do.....	.....	.....	Aug. 4	.....	.....	10	.....
53	13	July 26	July 29	Aug. 3	...do.....	3	8	9	.....
54	16	...do.....	.....	.....	Aug. 5	.....	.....	10	.....
55	1	July 27	July 30	Aug. 3	...do.....	3	7	9	.....
56	15	...do.....	.....	.....	Aug. 6	.....	.....	10	.....
57	7	July 28	July 31	Aug. 4	...do.....	3	7	9	.....
58	16	...do.....	.....	.....	Aug. 7	.....	.....	10	.....
59	12	July 30	Aug. 3	Aug. 6	...do.....	4	7	8	.....
60	89	...do.....	.....	.....	Aug. 8	.....	.....	9	1
61	23	July 31	Aug. 4	Aug. 7	Aug. 9	4	7	9	.....
62	9	Aug. 1	...do.....	Aug. 8	...do.....	3	7	8	.....
63	18	Aug. 2	Aug. 5	Aug. 9	Aug. 10	3	7	8	.....
64	5	Aug. 3	Aug. 6	...do....	Aug. 11	3	6	8	.....
65	1	Aug. 5	Aug. 8	Aug. 11	Aug. 12	3	6	7	.....
Average						2.599	6.139	7.797	39
Maximum						5	10	13	.....
Minimum						2	5	6	.....

FIRST BROOD OF LARVÆ.

Time of hatching.—The first-brood larvæ commenced to hatch July 6. The last of the larvæ hatched August 12. Hatching, therefore, extended for a period of slightly over one month. The maximum number of larvæ hatched July 24. (See Table XXVIII.)

Length of the feeding period of the transforming larvæ.—During the season of 1914 two methods, namely, the stock-jar and bagged-fruit methods, were used for determining the feeding period of the first-brood larvæ. These methods are described on page 10.

As in 1913, only a very small number of the first-brood larvæ transformed to first-brood moths. Out of a total of 845 larvæ reared at the laboratory 12 (1.4 per cent) transformed.

In Table XXIX is given the length of the feeding period of the transforming larvæ of the first brood (stock-jar method). The average length of the feeding period for male and female larvæ was 19.666 days; maximum, 21 days; minimum, 17 days. Average for male larvæ, 21 days; maximum, 21 days; minimum, 21 days. Average for female larvæ, 19.285 days; maximum, 21 days; minimum, 17 days.

TABLE XXIX.—*Length of feeding period of transforming larvæ of the first brood, stock-jar method, Winthrop, Me., 1914.*

No. of observation.	Date of—		Sex.	Days of feeding.
	Hatching.	Leaving fruit.		
1	July 6	July 24	♀	18
2	...do....	July 27	♂	21
3	July 8	...do....	♀	19
4	...do....	July 28	♀	20
5	...do....	July 29	♂	21
6	July 9	...do....	♀	20
7	July 10	July 27	♀	17
8	...do....	July 31	♀	21
9	July 13	Aug. 2	♀	20

Average length of feeding period, male and female larvæ, 19.666 days; male, 21 days; female, 19.285 days.
Maximum length of feeding period, male and female larvæ, 21 days; male, 21 days; female, 21 days.
Minimum length of feeding period, male and female larvæ, 17 days; male, 21 days; female, 17 days.

The length of the feeding period of the transforming larvæ of the first brood (bagged-fruit method) is given in Table XXX. The average length of the feeding period was 25.333 days; maximum, 26 days; minimum, 24 days. The average for the male larvæ was 25 days; maximum, 26 days; minimum, 24 days. No record for female larvæ was secured.

The average feeding period for all transforming larvæ was 21.082 days, as given in Table XXXVIII.

TABLE XXX.—*Length of the feeding period of transforming larvæ of the first brood, bagged-fruit method, Winthrop, Me., 1914.*

No. of observation.	Date of—		Sex.	Days of feeding.
	Hatching.	Leaving fruit.		
1	July 15	Aug. 10	.....	26
2	July 17	...do....	♂	24
3	July 19	Aug. 14	♂	26

Average length of feeding period, male and female larvæ, 25.333 days; male, 25 days.
Maximum length of feeding period, male and female larvæ, 26 days; male, 26 days.
Minimum length of feeding period, male and female larvæ, 24 days; male, 24 days.

Length of the feeding period of wintering first-brood larvæ (stock-jar method).—Observations were taken on the length of feeding of 341 larvæ, as is given in Table XXXI. The average length of the feeding period for all larvæ was 25.717 days; maximum, 46 days; minimum, 19 days. The average length of feeding for the male larvæ was 23.935 days; for the female larvæ, 27.022 days. The maximum length of the feeding period for the male larvæ was 46 days; for the female larvæ, 46 days. The minimum length of the feeding period for the male larvæ was 19 days; for the female larvæ, 19 days.

TABLE XXXI.—*Length of feeding period of the wintering larvæ of the first brood, stock-jar method, Winthrop, Me., 1914.*

[Figures in parentheses ( ) denote sex undetermined.]

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.															
		19		20		21		22		23		24		25		26	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
2	July 7				1							1					
4	July 8					1				1			1				1
2	July 9														1		
5	July 11		1				1			1		1					
4	July 12	1	1		1		1										
3	July 13			1			1					(1)					
9	July 14			1			1							1	1	(1)	
14	July 15									1		2	3	1			
9	July 16															1	1
18	July 17							1				2	1	2	2	1	1
11	July 18									1	1	1	2				
19	July 19									1	1		2	1	(1)		
3	July 20									1		1					
20	July 21									1		(1)2	1		4		
6	July 22							1		1					1	1	1
6	July 23										2	1	3				
11	July 24		1					1		1		1	2				2
33	July 25							1	1	1	4	2	4	1	(1)	1(1)	3
4	July 26													1	1		
9	July 28							(1)			1		2		2		
10	July 29											1	3		2		2
19	July 31					1		3	1	1	4	1	3	1			
24	Aug. 1			1	(1)	3		2	1	2	4	4	3		1		1
16	Aug. 2					1					3	2	1	2	3	1	1
40	Aug. 3			1	1	4	1	3(1)	1	3	1	5	2	(2)	1		1
13	Aug. 4						1	(1)	1	1	(1)		1	1			2
10	Aug. 5					3		2		1			1	2			
5	Aug. 6								1					1	2	1	
10	Aug. 8											1	1	3	1	2	
2	Aug. 9																
341 ♂ and ♀		1	3	4	3	13	6	14	6	18	21	28	36	17	22	8	16
Sex undetermined		0		1		0		3		1		2		4		2	
Total		4		8		19		23		40		66		43		26	

TABLE XXXI.—*Length of feeding period of the wintering larvæ of the first brood, stock-jar method, Winthrop, Me., 1914*—Continued.

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.															
		27		28		29		30		31		32		33		34	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
2	July 7																
4	July 8																
2	July 9										1						
5	July 11					(1)											
4	July 12																
3	July 13																
9	July 14		1		1					1	1						
14	July 15	2		1		1											
9	July 16									(1)2	2						
18	July 17	1		1	1	2		1		2							
11	July 18		2	2	1		1										
19	July 19	(1)	3		1		1		2			1	1				
3	July 20	1															
20	July 21		2	2	2	(1)		1					1			1	
6	July 22			1													
6	July 23																
11	July 24				1		1										
33	July 25	(2)		(1)1	3	1	1		1				1	1			
4	July 26			2													
9	July 28		2						1								
10	July 29													(1)			1
19	July 31	1													1		1
24	Aug. 1								1								
16	Aug. 2							(1)	1								
40	Aug. 3	1	1	1	2	1(1)	4						1		1		
13	Aug. 4			1(1)	2												
10	Aug. 5						1										
5	Aug. 6																
10	Aug. 8				2												
2	Aug. 9	1					1										
341 ♂ and ♀		7	11	12	16	5	10	2	6	5	4	1	4	1	2	1	2
Sex undetermined		3		2		3		1		1		0		1		0	
Total		21		30		18		9		10		5		4		3	

TABLE XXXI.—*Length of feeding period of the wintering larvæ of the first brood, stock-jar method, Winthrop, Me., 1914*—Continued.

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.													
		35		36		37		38		40		41		46	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
2	July 7														
4	July 8														
2	July 9														
5	July 11														
4	July 12														
3	July 13														
9	July 14														
14	July 15				1	1			1						
9	July 16	(1)									1				
18	July 17														
11	July 18														
19	July 19											1		1	1
3	July 20														
20	July 21						1								
6	July 22														
6	July 23														
11	July 24		1												
33	July 25				1										
4	July 26														
9	July 28														
10	July 29														
19	July 31		1												
24	Aug. 1														
16	Aug. 2														
40	Aug. 3														
13	Aug. 4														
10	Aug. 5														
5	Aug. 6														
10	Aug. 8														
2	Aug. 9														
341 ♂ and ♀		0	2	0	2	1	1	0	1	0	1	1	0	1	1
Sex undetermined		1		0		0		0		0		0		0	
Total		3		2		2		1		1		1		2	

Average length of feeding period, 341 male and female larvæ, 25.717 days; 140 male larvæ, 23.935 days; 176 female larvæ, 27.022 days.

Maximum length of feeding period, 341 male and female larvæ, 46 days; 140 male larvæ, 46 days; 176 female larvæ, 46 days.

Minimum length of feeding period, 341 male and female larvæ, 19 days; 140 male larvæ, 19 days; 176 female larvæ, 19 days.

Length of the feeding period of wintering first-brood larvæ (bagged-fruit method).—Table XXXII records the feeding period of 492 wintering first-brood larvæ. The average feeding period of these larvæ was 31.865 days; maximum, 55 days; minimum, 24 days. The average feeding period for 226 male larvæ was 30.960 days; maximum, 55 days; minimum, 24 days. The average feeding period for 213 female larvæ was 32.436 days; maximum, 55 days; minimum, 25 days.

TABLE XXXII.—*Length of feeding period of the wintering larvæ of the first brood, bagged-fruit method, Winthrop, Me., 1914.*

[Figures in parentheses ( ) denote sex undetermined.]

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.															
		24		25		26		27		28		29		30		31	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
20	July 10	....	....	(1)	1	....	....	2	1(1)	3	1	1(1)	2	....	....	....	....
8	July 11	....	....	(1)	....	2	....	....	....	....	....	....	....	1	....	2	1
22	July 13	....	....	1	1	1	....	4	4	(1)3	3	....	1	1	....	....	....
29	July 14	....	....	3	1(2)	1	2	4	2	4	2(3)	1	....	1	1	....	1
22	July 15	....	....	....	....	1	....	....	....	1	....	1	(1)	2	3	....	....
20	July 16	....	....	....	....	....	....	....	....	....	1	3	....	(1)2	1	1	2
42	July 17	1	....	....	....	(1)	1	3	....	3	3	....	1	(2)7	4	1	4
42	July 18	....	....	1	....	....	....	2	1	2	3	3	2	4	4	(1)1	2
21	July 19	....	....	....	....	1	....	....	....	1	....	5	1	1	....	2	....
18	July 20	....	....	2	....	....	1	1	1	....	....	2	2	....	....	1	1
21	July 21	1	....	....	....	2	....	....	....	....	....	2	1	1	3	....	2
16	July 22	....	....	(1)	1	....	1	2	....	....	....	2	....	....	1	....	1
13	July 23	....	....	....	....	2	....	1	1	1	1	....	....	1	2	....	1
20	July 24	....	....	....	....	....	1	2	....	....	....	2	1	2	....	1	....
42	July 25	....	....	....	....	....	....	(2)	....	1	2	4	(1)4	2	1	1	....
13	July 26	....	....	....	....	1	....	....	1	....	....	1	....	1	....	....	2
8	July 27	....	....	....	....	....	....	....	....	....	....	....	....	3	....	....	....
12	July 28	....	....	....	....	....	....	....	....	1	....	....	....	1	....	....	....
8	July 30	....	....	....	....	....	....	....	....	1	....	....	....	1	....	....	....
14	July 31	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....
3	Aug. 2	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....
28	Aug. 3	....	....	....	....	....	....	....	....	....	....	2	3	2	....	....	1
14	Aug. 4	....	....	....	....	....	....	....	....	1	....	1	....	....	....	1	....
1	Aug. 5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
4	Aug. 6	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
5	Aug. 7	....	....	....	....	....	....	....	....	1	....	....	....	....	....	1	....
15	Aug. 8	....	....	....	....	....	....	....	....	1	....	....	....	....	....	1	....
6	Aug. 9	....	....	....	....	....	....	....	....	1	....	....	2	....	....	....	....
3	Aug. 10	....	....	....	....	1	....	....	....	....	....	....	....	....	....	(1)	....
2	Aug. 11	....	....	....	....	....	....	....	....	1	1	....	....	....	....	....	....
492 ♂ and ♀		2	0	7	4	12	6	21	11	26	17	30	20	35	20	13	18
Sex undetermined		0		5		1		3		4		3		3		2	
Total		2		16		19		35		47		53		58		33	

TABLE XXXII.—*Length of feeding period of the wintering larvæ of the first brood, bagged-fruit method, Winthrop, Me., 1914*—Continued.

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.															
		32		33		34		35		36		37		38		39	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
20	July 10								1	2							
8	July 11						1										
22	July 13	(2)															
29	July 14				1												
22	July 15	3	2	1	(1)2				4								
20	July 16		1	2	(1)2		2		1								
42	July 17		2	1	1	2	1		1				2				
42	July 18	(1)2	1	3	(1)4			1									
21	July 19	2	2	1	1		2				1					(1)	
18	July 20	1	(3)			(2)		1									
21	July 21	3	2	3									1				
16	July 22		2			1	1	1	1		1						
13	July 23		1	1									1				
20	July 24	1	1				1	1	2			1			1	(1)	1
42	July 25	2	3	1	2				1	3	1	2	1	1	2	(1)	2
13	July 26	1	1								2						2
8	July 27		2		(1)	2											
12	July 28	1(1)	1					1(1)	1			1	2	(1)			
8	July 30		1				2		1					1		1	
14	July 31	1	1		3	(1)	1		2		1	1				(1)	
3	Aug. 2				1		1										
28	Aug. 3				1	1		1	2	1	1	2	1				
14	Aug. 4				2		2	2								1	1
1	Aug. 5																
4	Aug. 6	1	1														1
5	Aug. 7			1		1				1							
15	Aug. 8	1						1					1	1(1)	3	(1)	
6	Aug. 9															(1)	1
3	Aug. 10								1								
2	Aug. 11																
492 ♂ and ♀		19	24	14	20	7	14	9	18	7	7	8	8	3	6	2	8
Sex undetermined		7		4		3		1		0		0		2		6	
Total		50		38		24		28		14		16		11		16	

TABLE XXXII.—*Length of feeding period of the wintering larvæ of the first brood, bagged-fruit method, Winthrop, Me., 1914*—Continued.

Number of individuals.	Date of entering fruit.	Length of feeding period in specified days.																	
		40		41		42		43		44		45		46		48		55	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
20	July 10			1														1	1
8	July 11																		
22	July 13																		
29	July 14																		
22	July 15																		
20	July 16																		
42	July 17												1						
42	July 18			1						(1)		1							
21	July 19																		
18	July 20																		
21	July 21																		
16	July 22																		
13	July 23																		
20	July 24																	1	
42	July 25		1			1													
13	July 26							1											
8	July 27																		
12	July 28																		
8	July 30																		
14	July 31			1															
3	Aug. 2																		
28	Aug. 3	(1)	4	1		1	1	(1)							1				
14	Aug. 4				1	(2)													
1	Aug. 5				(1)														
4	Aug. 6															1			
5	Aug. 7																		
15	Aug. 8					1				(2)				(1)					
6	Aug. 9		1																
3	Aug. 10																		
2	Aug. 11																		
492 ♂ and ♀		0	6	4	1	3	1	1	0	0	0	1	1	0	1	1	1	1	1
Sex undetermined		1		1		2		1		3		0		1		0		0	
Total		7		6		6		2		3		2		2		2		2	

Average length of feeding period, 492 male and female larvæ, 31.865 days; 226 male larvæ, 30.960 days; 213 female larvæ, 32.436 days.

Maximum length of feeding period, 492 male and female larvæ, 55 days; 226 male larvæ, 55 days; 213 female larvæ, 55 days.

Minimum length of feeding period, 492 male and female larvæ, 24 days; 226 male larvæ, 24 days; 213 female larvæ, 25 days.

As was noted in 1913, the average feeding period of the transforming larvæ was shorter than that of the overwintering larvæ. Likewise the feeding period of the larvæ reared by the bagged-fruit method was longer than the feeding period of larvæ reared by any other method. The fact that female larvæ feed on an average for a longer time than the male larvæ was again proven in 1914.

Larval life in the cocoon.—The average number of days spent by the larvæ in constructing their cocoons was 6.166; maximum, 9 days; minimum, 3 days. (See Table XXXIII.)

TABLE XXXIII.—*Length of the pupal stage of the first brood, Winthrop, Me., 1914.*

No. of observation.	Date of—			Making of cocoon.	Pupal period.	No. of observation.	Date of—			Making of cocoon.	Pupal period.
	Leaving fruit.	Pupation.	Emergence.				Leaving fruit.	Pupation.	Emergence.		
				Days.	*Days.*					*Days.*	*Days.*
1	July 24	July 27	Aug. 11	3	15	7	July 29	Aug. 5	Aug. 18	7	13
2	July 27	Aug. 3	Aug. 17	7	14	8	July 31	Aug. 6	Aug. 20	6	14
3	...do.....	...do.....	...do.....	7	14	9	Aug. 2	Aug. 9	Aug. 27	7	18
4	...do.....	Aug. 4	Aug. 18	8	14	10	Aug. 10	Aug. 15	Sept. 2	5	18
5	July 28	Aug. 6	Aug. 20	9	14	11	...do.....	Aug. 18	Sept. 5	8	18
6	July 29	Aug. 2	Aug. 16	4	14	12	Aug. 14	Aug. 17	Sept. 3	3	17
Average										6.166	15.250
Maximum										9	18
Minimum										3	13

FIRST BROOD OF PUPÆ OR SUMMER PUPÆ.

Time of pupation.—Pupation of the first brood commenced July 27 and extended until August 18, as shown in Table XXXIII. (See fig. 7.)

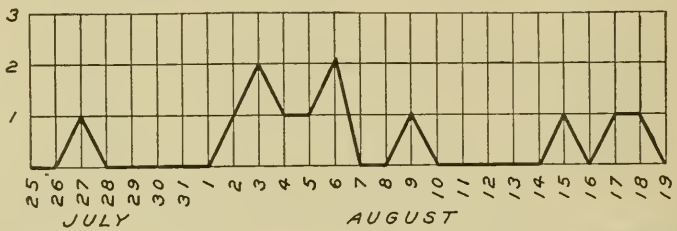

FIG. 7.—Diagram showing pupation of the first brood of the codling moth in 1914 at Winthrop, Me. (Original.)

Length of the pupal stage.—Table XXXIII records the length of the pupal period of 12 individuals. As will be noted, the average length of the pupal period was 15.250 days; maximum, 18 days; minimum, 13 days.

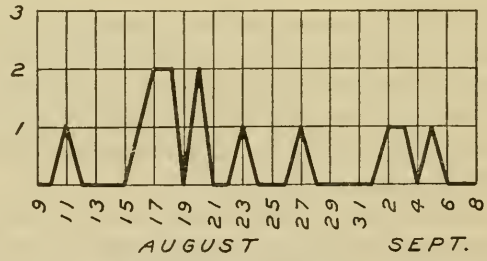

FIG. 8.—Diagram showing emergence of the first brood of moths of the codling moth in 1914 at Winthrop, Me. (Original.)

FIRST OR SUMMER BROOD OF MOTHS.

Time of emergence.—The moths of the summer brood commenced to issue August 11. The last moth emerged September 5. The record of the moth emergence is given in Table XXXIV. (See fig. 8.)

TABLE XXXIV.—*Time of emergence of moths of the first or summer brood, Winthrop, Me., 1914.*

Date of emergence.	Total emergence.	Date of emergence.	Total emergence.
Aug. 11	1	Aug. 27	1
Aug. 16	1	Sept. 2	1
Aug. 17	2	Sept. 3	1
Aug. 18	2	Sept. 5	1
Aug. 20	2		
Aug. 23	1		13

Time of oviposition.—As shown in Table XXXV, the first eggs were deposited by the summer-brood moths on August 20. The last oviposition occurred September 20.

TABLE XXXV.—*First or summer brood of moths, Winthrop, Me., 1914.*

CAGE I.					CAGE II.				
Date.	Number of moths emerged.	Eggs deposited.	Death of moths.		Date.	Number of moths emerged.	Eggs deposited.	Death of moths.	
			Male.	Female.				Male.	Female.
Aug. 11	1	.....	.....	.....	Sept. 2	1	.....	.....	.....
Aug. 16	1	.....	.....	.....	Sept. 3	1	.....	.....	.....
Aug. 17	2	.....	.....	.....	Sept. 5	1	.....	.....	.....
Aug. 18	2	.....	.....	.....	Sept. 7	.....	Eggs..	.....	.....
Aug. 20	2	Eggs..	.....	.....	Sept. 10	.....	...do...	.....	.....
Aug. 22	.....	...do...	.....	.....	Sept. 11	.....	...do...	.....	.....
Aug. 23	1	.....	.....	.....	Sept. 12	.....	...do...	.....	.....
Aug. 24	.....	Eggs..	.....	.....	Sept. 13	.....	...do...	.....	.....
Aug. 25	.....	...do...	.....	.....	Sept. 14	.....	...do...	.....	.....
Aug. 26	.....	.....	.....	1	Sept. 15	.....	...do...	.....	.....
Aug. 28	.....	Eggs..	.....	.....	Sept. 18	.....	...do...	.....	.....
Aug. 30	.....	.....	2	1	Sept. 20	.....	...do...	.....	1
Aug. 31	.....	.....	1	2	Sept. 21	.....	.....	.....	1
Sept. 2	.....	.....	.....	2	Sept. 22	.....	.....	1	.....
	9	.....	3	6		3	.....	1	2

Number of eggs per first-brood female moth.—The total number of eggs deposited by 8 female moths kept in confinement with male moths was 181. Hence the average number of eggs per female was 22.625.

LENGTH OF LIFE CYCLE OF THE FIRST GENERATION.

The life cycle of the first generation of the codling moth is given in two tables, Tables XXXVI and XXXVII. The life cycle considered in these tables extends from the time of egg deposition to the emergence of the moth and hence is not the complete life cycle. For the complete life cycle there should be added to the figures recorded about four days, which is the time from the emergence of the moth until the first oviposition. As will be noted in the tables, the average life cycle (stock-jar method) was 50.222 days; bagged-fruit method averaged for 3 individuals 55 days.

TABLE XXXVI.—*Life cycle of first generation of codling moth as observed by rearing at Winthrop, Me., 1914, stock-jar feeding method.*

No. of observation.	Date of—					Days for—				
	Egg deposition.	Hatching.	Larvæ leaving the fruit.	Pupation.	Emergence of moths.	Hatching.	Feeding.	Making of cocoon.	Pupal period.	Life cycle.[1]
1♀	June 24	July 6	July 24	July 27	Aug. 11	12	18	3	15	48
2♂	...do.....	...do.....	July 27	Aug. 3	Aug. 17	12	21	7	14	54
3♀	June 27	July 8	...do.....	...do.....	...do.....	11	19	7	14	51
4♀	...do.....	...do.....	July 28	Aug. 6	Aug. 20	11	20	9	14	54
5♂	...do.....	...do.....	July 29	Aug. 5	Aug. 18	11	21	7	13	52
6♀	July 1	July 9	...do.....	Aug. 2	Aug. 16	8	20	4	14	46
7♀	July 3	July 10	July 27	Aug. 4	Aug. 18	7	17	8	14	46
8♀	...do.....	...do.....	July 31	Aug. 6	Aug. 20	7	21	6	14	48
9♀	July 5	July 13	Aug. 2	Aug. 9	Aug. 27	8	20	7	18	53
Average						9.666	19.666	6.444	14.444	50.222
Maximum						12	21	9	18	54
Minimum						7	17	3	13	46

[1] Add 4 days for complete life cycle.

TABLE XXXVII.—*Life cycle of first generation of codling moth as observed by rearing at Winthrop, Me., 1914, bagged-fruit feeding method.*

No. of observation.	Date of—					Days for—				
	Egg deposition.	Hatching.	Larva leaving the fruit.	Pupation.	Emergence of moths.	Hatching.	Feeding.	Making of cocoon.	Pupal period.	Life cycle.[1]
1	July 8	July 15	Aug. 10	Aug. 15	Sept. 2	7	26	5	18	56
2♂	July 11	July 17	...do.....	Aug. 18	Sept. 5	6	24	8	18	56
3♂	July 12	July 19	Aug. 14	Aug. 17	Sept. 3	7	26	3	17	53
Average						6.666	25.333	5.333	17.666	55
Maximum						7	26	8	18	56
Minimum						6	24	3	17	53

[1] Add 4 days for complete life cycle.

A summary of Tables XXXVI and XXXVII is given in Table XXXVIII, which shows that the average life cycle of the first generation of all individuals was 51.416 days. The complete life cycle would be about 55–56 days.

TABLE XXXVIII.—*Summary of life cycle of first generation of codling moth, Winthrop, Me., 1914.*

	Number of observations.	Larval feeding method.	Days for—				
			Hatching.	Feeding.	Making of cocoon.	Pupal period.	Life cycle.[1]
Average life cycle	9	A	9.666	19.666	6.444	14.444	50.222
Do	3	B	6.666	25.333	5.333	17.666	55.000
Average of all life cycles	12	A+B	8.916	21.082	6.166	15.249	51.416

[1] Add 4 days for complete life cycle.

A, stock-jar method; B, bagged-fruit method.

THE SECOND GENERATION.

SECOND BROOD OF EGGS.

Length of incubation.—On August 20 the first egg of the second brood was deposited. Oviposition continued until September 18, reaching the maximum on August 31. Out of 138 eggs deposited 96 (69.56 per cent) hatched. The average incubation period was 10.208 days; maximum, 15 days; minimum, 8 days. The average time from the time of egg deposition to the appearance of the red ring was 4.754 days; maximum, 9 days; minimum, 3 days. The average time for the appearance of the black spot was 8.368 days; maximum, 14 days; minimum, 6 days. (See Table XXXIX.)

TABLE XXXIX.—*Length of incubation period of second-brood eggs. Winthrop, Me., 1914.*

No. of observation.	Number of eggs.	Date—				Appearance of—		Incubation period.	Number dead.
		Deposited.	Red ring.	Black spot.	Hatched.	Red ring.	Black spot.		
						Days.	*Days.*	*Days.*	
1	1	Aug. 20							1
2	8	Aug. 22							8
3	1	Aug. 24	Aug. 29	Sept. 2	Sept. 4	5	9	9	
4	13	Aug. 25	Aug. 30	...do	...do	5	8	10	
5	10	...do			Sept. 5			11	3
6	9	Aug. 26	Aug. 31	Sept. 3	...do	5	8	10	
7	7	...do			Sept. 6			11	3
8	1	Aug. 27	Sept. 1	Sept. 4	Sept. 8	5	8	12	
9	3	Aug. 28	Sept. 4	Sept. 6	Sept. 9	7	9	12	1
10	6	Aug. 31	Sept. 5	...do	Sept. 8	5	6	8	
11	28	...do			Sept. 9			9	4
12	10	Sept. 7	Sept. 12	Sept. 19	Sept. 21	5	12	14	1
13	3	Sept. 10	Sept. 15	Sept. 21		5	11		3
14	2	Sept. 11	...do	...do		4	10		2
15	1	Sept. 12	Sept. 21	Sept. 22	Sept. 23	9	10	11	
16	15	...do			Sept. 24			12	14
17	7	Sept. 13	Sept. 17	Sept. 21	Sept. 23	4	8	10	
18	3	...do			Sept. 24			11	
19	7	Sept. 14	Sept. 17	Sept. 20	Sept. 23	3	6	9	
20	3	Sept. 18	Sept. 22	Oct. 2	Oct. 3	4	14	15	2
Average						4.754	8.368	10.208	42
Maximum						9	14	15	
Minimum						3	6	8	

SECOND BROOD OF LARVÆ.

Time of hatching.—As will be noted in Table XXXIX, the first of the second-brood larvæ hatched September 4. The last of the second-brood larvæ hatched October 3. Hence the period of hatching was about one month.

Length of feeding period.—Observations on the length of the feeding period was limited to 4 individuals. Many of the larvæ which entered the fruit failed to mature. The average feeding period was 42.750 days; maximum, 47 days; minimum, 38 days. The above records are given in Table XL.

TABLE XL.—*Length of feeding period of second-brood larvæ, stock-jar method, Winthrop, Me., 1914.*

Number of larvæ.	Date of hatching.	Date of leaving fruit.	Sex.	Days of feeding.
1	Sept. 8	Oct. 16	♀	38
1	...do.....	Oct. 21	♂	43
1	...do.....	...do.....	♂	43
1	...do.....	Oct. 25	.....	47
Average				42.75

BAND-RECORD EXPERIMENT, 1914.

During the season of 1914 a total of 499 larvæ was collected from banded trees. The first larvæ left the fruit August 3, the last October 11. None of these larvæ transformed. (See Table XLI.)

TABLE XLI.—*Band-record experiment, Winthrop, Me., 1914.*

Number of record.	Date of collecting.	Number of larvæ.	Number of moths, 1914.	Number of parasites, 1914.	No. of record.	Date of collecting.	Number of larvæ.	Number of moths, 1914.	Number of parasites, 1914.
1	Aug. 3	1	0	0	14	Sept. 11	20	0	0
2	Aug. 6	3	0	0	15	Sept. 14	31	0	0
3	Aug. 9	0	0	0	16	Sept. 17	43	0	0
4	Aug. 12	7	0	0	17	Sept. 20	42	0	0
5	Aug. 15	1	0	0	18	Sept. 23	54	0	0
6	Aug. 18	2	0	0	19	Sept. 26	16	0	0
7	Aug. 21	15	0	0	20	Sept. 29	0	0	0
8	Aug. 24	8	0	0	21	Oct. 2	6	0	0
9	Aug. 27	17	0	0	22	Oct. 5	11	0	0
10	Aug. 30	23	0	0	23	Oct. 8	2	0	0
11	Sept. 2	30	0	0	24	Oct. 11	5	0	0
12	Sept. 5	82	0	0					
13	Sept. 8	80	0	0			499	0	0

COMPARISON OF THE LIFE HISTORY OF THE CODLING MOTH IN 1913 AND 1914.

A comparison of the life history of the codling moth is shown diagrammatically in figure 9. This chart shows the beginning and ending of the different stages of the insect, and, in a general way, the maximum of activity for each phase of the life history. It will be noted that the life histories of the species during 1913 and 1914 corresponded quite closely. Variations were due chiefly to climatic differences which were of comparatively short duration.

In 1913 pupation began somewhat earlier than in 1914. An unusually warm period during the latter part of April and again during the first few days of May, 1913, doubtless exerted some influence on the larvæ. The very early pupæ in 1913, however, were evidently somewhat abnormal and failed to transform to moths. Pupation during both seasons ceased at approximately the same time. The average pupation period of the spring-brood pupæ in 1913 was 19.030 days; in 1914, 22.581 days.

FIG. 9.—Diagram of the seasonal history of the codling moth during the seasons of 1913 and 1914 at Winthrop, Me. (Original.)

In 1913 apples were in bloom from about May 18 to June 4, when the last of the petals had fallen. The temperatures during the blooming period were relatively low, accompanied by considerable precipitation. In 1914 the blooming period was favored with somewhat better weather conditions and, as a result of these climatic conditions, the moths of the spring brood began to issue a few days earlier than in 1913.

The average length of the life of the male spring-brood moth in 1913 was 10.685 days; of the female moth, 12.253 days. In 1914 the average life of the male moth was 13.708 days; female moth, 13.621 days.

Oviposition by moths of the spring brood began at very nearly the same time each year. In 1914, however, the period of oviposition extended about two weeks longer than in the preceding year. The average duration of the oviposition period in 1913 was 14.086 days; in 1914, 13.636 days.

Hatching of the first-brood eggs in 1913 began a few days prior to the date of the earliest hatching in 1914. Likewise hatching ceased in 1913 about three days earlier than in 1914. The average incubation period of the first-brood eggs in 1913 was 8.874 days; in 1914, 7.797 days.

The time of leaving the fruit by transforming larvæ of the first brood was approximately the same during each season. The average feeding period of the tranforming larvæ in 1913 was 23.432 days; in 1914, 21.082 days.

The time of leaving the fruit by the overwintering larvæ of the first brood was, during both seasons, a few days later than the time when the earliest transforming larvæ left the fruit. The period of leaving the fruit extended over a longer time in 1914 than in the preceding year. The average feeding period for the overwintering first-brood larvæ in 1913 was 27.884 days; in 1914, 29.348 days.

The pupation period of the first or summer brood covered practically the same time during 1913 and 1914, being slightly earlier in the latter year. The average length of the pupal stage in 1913 was 15.066 days; in 1914, 15.250 days.

The emergence of the first or summer brood of moths extended over approximately the same period during both seasons, being slightly earlier in 1913 than in the following year.

Oviposition by moths of the first or summer brood commenced about five days earlier and ceased about five days later in 1913 than in the following year.

The average life cycle of the first generation in 1913 was 51.566 days; in 1914, 51.416 days. Add four days for complete life cycle.

Hatching of the second-brood larvæ commenced about 12 days earlier in 1913 than in 1914. The average incubation period in 1913 was 11.862 days; in 1914, 10.208 days.

The second brood of larvæ left the fruit over a considerably longer period in 1913 than in the following year. This was due to the smaller number of individuals under observation in 1914 and to the warm weather conditions in November, 1913. The United States Weather Bureau (Climatological Service, North Atlantic States, November, 1913) reports that the "high temperatures caused unusual manifestations in nature." The average feeding period of the second-brood larvæ in 1913 was 49.160 days; in 1914, 42.750 days. The higher average in 1913 was due to the larger number of individuals which were leaving the fruit from September 25 to November 21.

THE CONTROL OF THE CODLING MOTH IN MAINE.

In connection with the life-history studies of the codling moth a series of spraying experiments was conducted in 1913 and 1914. As a result of these investigations it was found that one thorough spray application, as soon as the petals have fallen, is sufficient to control the codling moth. Arsenate of lead, paste 2 pounds or powder 1 pound to each 50 gallons of water, is recommended.

The proper time to spray is illustrated in Plate I. The spraying should be completed before the calyx cup closes too tightly, in order to fill each cup with the poison. This is of vital importance.

SUMMARY AND CONCLUSIONS.

The life-history studies of the codling moth herein recorded were conducted during the seasons of 1913 and 1914 at Winthrop, Me.

The codling moth in Maine has one full generation, a very small percentage (1 to 2 per cent) of the individuals of which transforms to make a partial second generation.

Pupation of the overwintering larvæ begins about the middle of May and extends to the first part of July. The length of the spring-brood pupal stage averaged 21 days.

The moths of the spring brood begin to emerge about two weeks after the petals have fallen and continue to issue for a period of about a month.

The average time from the date of emergence of the moths to first oviposition was about four days.

The oviposition of the spring-brood moths averaged 14 days.

The average length of life of the male spring-brood moth was about 12 days; of the female spring-brood moth about 13 days.

The earliest first-brood eggs were deposited approximately three weeks after the petals dropped.

The incubation period of the first-brood eggs averaged eight days.

The first-brood eggs began to hatch in from four to five weeks after the petals had fallen.

The transforming larvæ of the first brood fed for a period of about 22 days.

The overwintering larvæ of the first brood had an average feeding period of 28 days.

The female larvæ of the first brood fed for a longer period than the male.

The average time spent by the transforming larvæ in constructing their cocoons was about six days.

Approximately from 1 to 2 per cent of the first-brood larvæ transformed to first-brood pupæ. The remainder of the larvæ did not transform until the following spring (spring pupæ).

Pupation of the first or summer brood commenced during the latter part of July. The average length of the first-brood pupal stage was 15 days.

The first or summer brood of moths began to emerge just previous to mid-August and continued to issue for a period of about one month.

Oviposition by moths of the first brood began about mid-August.

The life cycle of the first generation was 51 days. The complete life cycle was about 55 days.

The average incubation period of the second brood of eggs was 11 days.

The average feeding period of the second-brood larvæ was 46 days.

The female larvæ of the second brood fed for a longer time than the male.

The hymenopterous parasite *Ascogaster carpocapsæ* Vier. was frequently reared.

The well-known beetle enemy *Tenebroides corticalis* Melsh. was commonly found attacking codling-moth larvæ.

The codling moth in Maine may be controlled with one spray thoroughly applied as soon as the petals drop. Arsenate of lead, paste 2 pounds or powder 1 pound to each 50 gallons of water, is recommended.

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DIV. INSECTS.

UNITED STATES DEPARTMENT OF AGRICULTURE

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Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

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THE SHARP-HEADED GRAIN LEAFHOPPER.

By EDMUND H. GIBSON, *Entomological Assistant, Cereal and Forage Insect Investigations.*

INTRODUCTION.

The sharp-headed grain jassid or leafhopper (*Draeculacephala mollipes* Say) has long been known to infest cereal and forage crops, principally grains and grasses. It is probably one of the most commonly observed insects of the farm, ranging throughout practically the entire United States. However, as Prof. Herbert Osborn remarks,[1] "it seems to have received much less notice from the economic standpoint than it merits."

The observations and facts set forth in this paper are the result of an entire year's work on the species in the Salt River Valley of Arizona during 1914, together with occasional observations elsewhere. With these data have been included the results of various miscellaneous observations made by other assistants engaged in cereal and forage insect investigations in the Bureau of Entomology.

The most extended account of this species previously published is included by Prof. Herbert Osborn [1] in Bulletin 108 of the Bureau of Entomology, and the aim of the present paper is to supplement Prof. Osborn's excellent treatise from which the author has freely quoted. The sharp-headed grain jassid was described by Say in 1831, mentioned by Dr. Asa Fitch in his list of insects in 1851, and was commented upon by Prof. P. R. Uhler in 1884. Prof. H. Garman describes it as a corn pest in 1890 in the second Annual Report of the Kentucky Agricultural Experiment Station, and Prof. Osborn gave an account of the species in Bulletin 22, Division of Entomology, U. S. Department of Agriculture, and in 1891, 1892, and 1897 added materially to the knowledge of the species, his account in 1912 being the last published treatise on the species.

[1] Osborn, Herbert. Leafhoppers affecting cereals, grasses, and forage crops. U. S. Dept. Agr., Bur. Ent., Bul. 108, 123 p., 29 fig., 4 pl., Sept. 12, 1912. See p. 56.

NOTE.—This paper is of interest to entomologists throughout the United States.

ECONOMIC IMPORTANCE AND MODE OF INJURY.

The economic importance of the Jassidæ has never been fully appreciated by the farmer and planter, nor have these insects been given the attention which they deserve, even by entomologists. Especially is this true of the sharp-headed grain jassid, one of the most widely distributed species with a great variety of food plants. While it probably may not become a destructive pest over wide areas, there is always the possibility of local outbreaks which may cause serious injury and temporary losses, as exemplified by the attack upon 180 acres of corn on the farm of Dr. O. R. Stewart, Palatka, Ark., during July, 1912. It no doubt occurs in small numbers every year over its entire range of distribution and causes secondary injury to grain and pasture grasses by attacking vigorous growing plants, hindering and interfering with their growth and development, and already weakened and unhealthy plants, hastening their death or permanently dwarfing them.

The greatest damage inflicted by the sharp-headed leafhopper is to young and tender grain crops by the feeding of nymphs and adults during the fall and early spring months. To corn and other crops the greater damage is done during the summer months. Because alfalfa is of such rapid growth the apparent injury to the crop will probably always be very slight.

There are three classes of injury, the most important of which is the direct injury caused by the feeding of nymphs and adults, in puncturing leaf and stem tissue and sucking the juices therefrom. An occasional feeding puncture in a leaf or stem would not of itself do appreciable harm, but when there is a concentrated attack upon a plant by from 10 to 50 nymphs or adults the injury becomes appreciable. In many instances the author has observed leaves withered throughout from this cause. The early stages of injury are indicated by a yellowing of the tissue around the feeding punctures, which are in themselves so small as to be hardly visible to the naked eye. Following the yellowing there is a drying and deadening of tissue which turns reddish brown, giving the leaf or stem a spotted appearance.

Ordinarily the feeding of the nymphs is more injurious to a plant than that of the adults because usually there are to be found a great many more nymphs than adults on the same plant. It is believed that nymphs, after hatching from the eggs, often remain on the same plant during the first two or three instars. The feeding of the nymphs in grain is practically limited to the throats of the plants; however, they will feed on almost any tender or succulent part. In the case of alfalfa the feeding is done on the underside of the leaves and upon young tender stems. The adults feed freely upon

the stems and leaves, especially along the midribs, of grains, grasses, and alfalfa. Their feeding causes very young alfalfa plants to grow slim and spindling.

Another form of injury is produced by the adult female in puncturing and constructing in leaves and stems the pockets for oviposition. A slit is made in the leaf or stem, and the eggs are thrust through this slit under the epidermis. These egg pockets cause a distortion of the surrounding plant tissue which later turns yellow. When four or five egg pockets are made in a single leaf of a young grain plant the injury resulting to the leaf is quite marked, and when several leaves on the same plant, as is often the case, are so affected, the entire plant is bound to be more or less injured.

The third mode of injury is caused by spores of fungous diseases gaining entrance to the plant tissue through the feeding punctures and egg-pocket slits. It is more than probable, but as yet has not been positively determined, that jassids themselves carry and disseminate the spores of rust and other fungous diseases.

DISTRIBUTION.

As Prof. Osborn has noted,[1] this jassid has an extremely wide distribution. In this country it ranges from the Atlantic to the Pacific and from the strictly boreal portions of Canada south into Mexico. It has been recorded by assistants of the Bureau of Entomology from 35 States, representing all sections of the United States excepting New England, where, although in all probability it occurs, no available records show its presence.

FOOD PLANTS.

The author has taken the nymphs and adults in large numbers from wheat, barley, oats, alfalfa, bur clover (*Medicago denticulata*), sour clover (*Melilotus indica*), Johnson grass (*Sorghum halepense*), wall barley (*Hordeum murinum*), and many other native grasses of the south and southwest. The adults alone have been observed feeding upon kafir corn, sorghum, cowpeas, vetch, and Bermuda grass. In addition to this list Prof. Osborn reports[1] having taken the species from rye, bluegrass, and brome grass. Other assistants of the Bureau of Entomology have noted the species as feeding on corn and timothy. It is very likely that a complete list of food plants would include several other cultivated crops and innumerable weeds.

DESCRIPTION.

The following is a copy of the technical description (*Tettigonia mollipes*) by Say, published in 1831:

Body yellow; head elongated, acute before; beneath the eyes a brown line, which is contained on the pectus; thorax green, a broad anterior and lateral yellow margin;

[1] Op. cit., p. 57.

scutel greenish-yellow; hemelytra green; nervures paler; exterior and apical margins pale yellow or whitish; a pale yellowish, capillary, oblique line from the humerus to the inner margin; tergum black-purple, lateral edge and tip yellow.

Length to the tip of the hemelytra over three-tenths of an inch.

A common species.

A simple description which will enable the farmer or uninitiated to recognize the species in its several stages is given below:

ADULTS.

(Fig. 1, *a–f*.)

Color bright grass-green, head very sharply pointed, of a slightly lighter green than body. Face marked with oblique lines. Males noticeably smaller than females, and with black venter. Venter of female lighter than wing covers.

EGGS.

(Fig. 1, *k*.)

The eggs are white; when first deposited they are rather transparent, later becoming opaque. They are irregularly elongate in form, comparatively blunt at both ends, and about three times as long as wide. The head end of the egg is somewhat bulging. Eyes of the immature nymph show through the eggshell as red spots a few days before hatching takes place. Table I, taken from the notes of Mr. V. L. Wildermuth, an assistant of the Bureau of Entomology, gives the egg measurements.

TABLE I.—*Measurements of eggs of the sharp-headed grain leafhopper.*

Egg.	Length.	Maximum width.	Minimum width.
	Mm.	*Mm.*	*Mm.*
1	1.40	0.35	0.15
2	1.25	.40	.10
3	1.40	.40	.125
Average	1.35	.38	.125

NYMPHS.

(Fig. 1, *g–j*, *l*.)

In general the nymphs resemble adults in shape and color, the most noticeable difference being in absence of wings and wing covers, and in size.

First-instar nymphs (fig. 1, *l*).—Color light yellow-green, uniform but somewhat darker on dorsal side of last two abdominal segments. Legs a cottony white. One dorsal stripe of lighter yellow running

entire length of body from vertex to tip of abdomen. Two dark spots at rear of head, one on either side of dorsal stripe. No hairs

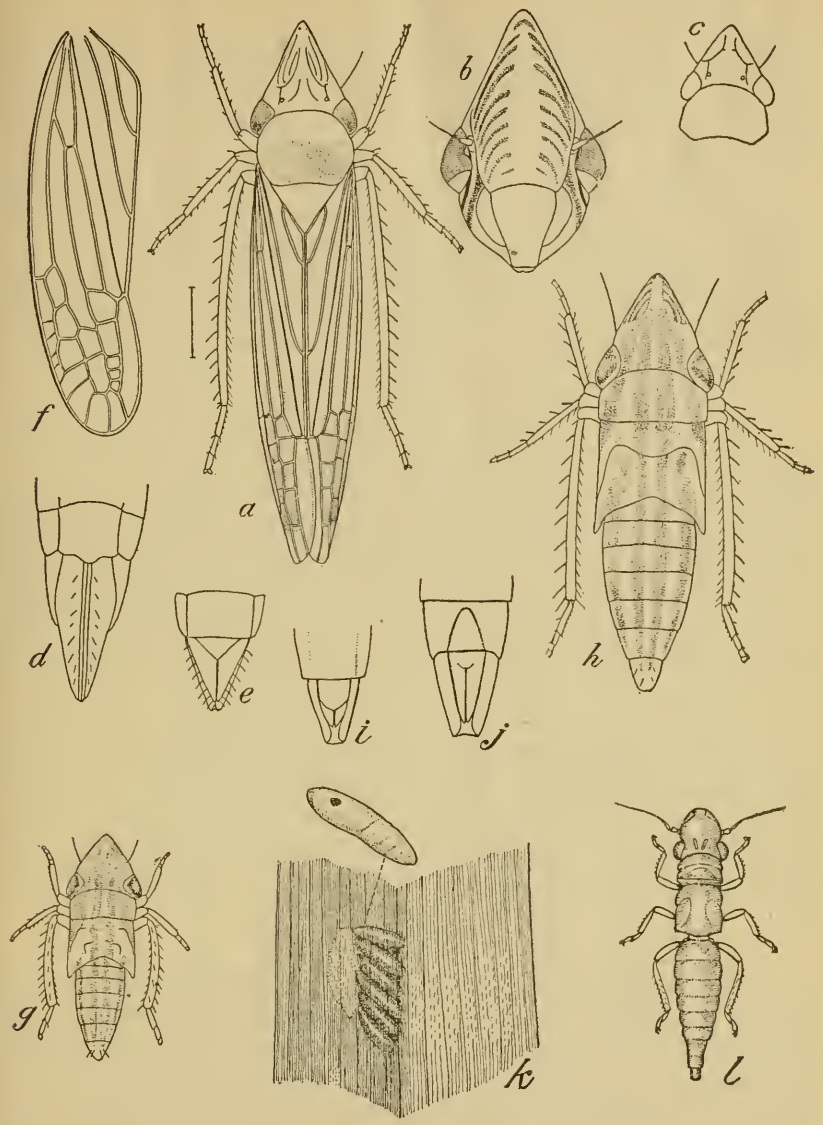

FIG. 1.—The sharp-headed grain leafhopper (*Draeculacephala mollipes*): *a*, Adult from above; *b*, face; *c*, vertex and pronotum; *d*, female genitalia; *e*, male genitalia; *f*, wing; *g*, *h*, nymphs; *i*, anal segment of last-stage nymph, showing genitalia of male; *j*, anal segment of last-stage nymph, showing female genitalia; *k*, eggs inserted in blade of wheat; *l*, freshly-hatched nymph. *a-k*, Enlarged; *l*, greatly enlarged. (*a-h*, From Osborn; *i-l*, original.)

or spines. Head very blunt, in contrast with nymphs of later instars. Average 1.5 mm. in length.

Second-instar nymphs.—Average length 2.5 mm. Head more pointed or acute. Black-line facial markings becoming distinct. Light median dorsal stripe remaining.

Third-instar nymphs.—Average length 3 mm. Spines on hind legs prominent. More mottled with gray markings. Head larger but not more pointed or acute. Dorsal stripe remains, extending to tip of abdomen. Eyes darker and more prominent. First indication of wing pads.

Fourth-instar nymphs.—Average length 4.2 mm. Head more pointed. Black-line facial markings very distinct. Dorsal stripe remaining. Spines on legs prominent. Wing pads larger.

Fifth-instar nymphs.—Average length 5 mm. Body darker green. Eyes slightly lighter green than body color. Hairs on tip of abdomen. Head slightly more pointed. Wing pads well developed and opaque.

COLOR FORMS OF ADULTS.

In 1913 Mr. Wildermuth noted many adults of a brown color. Thinking these might be another species specimens were sent to Prof. Osborn for determination, who replied to the effect that "the brown form is a variation of the green form which is usually the most common." The writer observed many of this brown form during January and February, 1914, but was unable to find a single brown individual during the spring and summer months. All adults reared from brown parents were entirely green and remained a true green until death. Because brown-form adults have been found only among the wintering adults the writer is inclined to believe that the brown coloration is due to a fading of the green pigment caused by prolonged life, as is the case with wintering adults, or by extreme weather changes. Recently Prof. Osborn has remarked that his "collection of brown individuals at El Paso, Tex., March 3, 1910, bears out the supposition that these may be old and faded specimens."

LIFE HISTORY AND HABITS.

As with all jassids, this species has three stages in its life cycle, namely, egg, nymph, and adult. The adult female deposits her eggs in pockets in leaves and stems, and these eggs hatch under Arizona conditions in from 3 to 35 days, depending upon the temperature. Through a series of five molts the nymphs increase in size, develop, and with the last molt transform to the adult. The length of the nymphal stage, as with the egg stage, depends largely upon the temperature, averaging 30 days in Arizona.

NUMBER OF GENERATIONS.

The number of generations a year will vary in different parts of the country according to the various climates, and is likely to fluctuate from year to year in accordance with seasonal variations. Prof.

Osborn remarks that in Ohio "there are clearly two distinct generations annually." In the Southern States, where there are more generations, these are not so clearly distinct, due to an overlapping of the three stages during the summer months. Because of this overlapping of the egg, nymphal, and adult stages it is very difficult to determine the exact number of generations from field observations. By the use of breeding cages it was possible to determine that there were six distinct generations for southern Arizona during 1914. The cage experiments checked up very closely with field observations. Thus the number of generations may vary from two to six.

For southern Arizona the first spring generation extended over February, March, and April; the second, over May and the first half of June; the third, over the last half of June and July; the fourth, over August; the fifth, over September; and the sixth, over October and November, the adults of the sixth generation living over winter and ovipositing in February for the following spring generation.

LENGTH OF EGG STAGE.

The length of the egg stage in southern Arizona was found to vary from 3 to 35 days, depending upon the temperature, the average being 12 days. Table II gives the length of the egg stage, with the corresponding temperatures, and plainly shows that the length is materially shortened during the summer months.

TABLE II.—*Length of the egg stage of the sharp-headed grain leafhopper, Tempe, Ariz., 1914.*

Number of eggs.	Date of oviposition.	Date of hatching.	Length of egg stage.	Average mean temperature during egg stage.
			Days.	°*F.*
4	Feb. 4	Mar. 11	35	59.0
16	Feb. 13	...do.....	26	61.7
6	Feb. 19	Mar. 12	21	67.4
6	Mar. 5	Mar. 20	15	65.9
3	Apr. 5	Apr. 20	15	70.4
5	May 8	May 16	8	74.3
7	May 11	May 18	7	74.3
8	...do.....	May 16	5	74.1
10	June 19	June 28	9	85.0
9	July 29	Aug. 1	3	93.0
14	Aug. 28	Sept. 2	15	82.8
20	Oct. 1	Oct. 5	4	71.0
		Average.....	12.75	

SUMMARY, SHOWING CONDENSED AVERAGES.

When length of egg stage averaged—	The average mean temperature was—
Days.	°*F.*
27.3	62.7
15.0	68.1
8.0	77.8
4.2	80.2

From the notes made by Mr. V. L. Wildermuth at Tempe, Ariz., during February and March, 1913, the length of the egg stage is shown in Table III to be practically the same as found by the writer for those months.

TABLE III.—*Length of egg stage of the sharp-headed grain leafhopper, Tempe, Ariz., February and March, 1913.*

Date of oviposition.	Date of hatching.	Length of egg stage.
		Days.
Feb. 21	Mar. 29	36
Feb. 25	Mar. 18	21
Feb. 27	Mar. 22	23
Feb. 27	Mar. 25	26
Average		26.5

LENGTH OF NYMPHAL STAGE.

As with the egg stage, the length of the nymphal stage varies with the temperature. Prof. Osborn's observations in Iowa show that the nymphal stages extend over from early spring until the latter part of June and from the second week in August until nearly winter. Where the temperatures are higher and the summer season more prolonged the length is considerably shortened. The observations at Tempe, Ariz., show that the average length varies from 20 to 51 days, according to the temperature. Table IV gives the length of the nymphal stage of each of the six generations and the length of each instar.

TABLE IV.—*Length of nymphal stage of the sharp-headed grain leafhopper. Tempe, Ariz., 1914.*

FIRST SPRING GENERATION, MARCH, APRIL, AND MAY, 1914.

Nymph emerged from egg.	Date of first molt.	Length of first instar.	Date of second molt.	Length of second instar.	Date of third molt.	Length of third instar.	Date of fourth molt.	Length of fourth instar.	Date of fifth molt.	Length of fifth instar.	Total length of nymphal stage.
		Days.		*Days.*		*Days.*		*Days.*		*Days.*	*Days.*
Mar. 4	Mar. 14	10	Mar. 25	11	Apr. 4	10	Apr. 13	9	Apr. 23	10	50
Do	Mar. 10	6	Mar. 18	8	Mar. 30	12	Apr. 8	9	Apr. 20	12	47
Mar. 10	Mar. 23	13	Apr. 2	10	Apr. 8	6	Apr. 14	6	Apr. 23	9	44
Do	Mar. 19	9	Mar. 28	9	Apr. 6	9	Apr. 13	7	Apr. 21	8	42
Mar. 8	Mar. 17	9	Apr. 1	15	...do	5	Apr. 11	5	Apr. 20	9	43
Mar. 11	Mar. 19	8							...do		40
Mar. 10	Mar. 24	14	Apr. 3	10	Apr. 8	5	Apr. 14	6	Apr. 25	11	46
Mar. 12	Mar. 26	14	Apr. 7	12	Apr. 16	9			Apr. 27		45
Mar. 8	Mar. 22	14	Apr. 2	11	Apr. 7	5	Apr. 17	10	Apr. 28	11	51
Mar. 10	Mar. 25	15	Apr. 6	12	Apr. 11	5	Apr. 20	9	Apr. 30	10	51
Mar. 20	Mar. 21	1	Apr. 1	11	Apr. 6	5	Apr. 14	8	...do	16	41
Mar. 6	Mar. 19	13	Apr. 3	15	Apr. 13	10	Apr. 17	4	May 2	15	57
Mar. 12	Mar. 27	15	Apr. 8	12	...do	5	Apr. 20	7	May 5	15	54
Mar. 7	Mar. 19	12	Apr. 1	13	Apr. 7	6	...do	13	May 6	16	60
Mar. 20	Apr. 6	17	Apr. 13	7	Apr. 16	3	Apr. 23	7	May 7	14	48
Mar. 8	Mar. 27	19	Apr. 6	10	Apr. 13	7	Apr. 20	7	...do	17	60
Mar. 20	Apr. 4	15	Apr. 11	7	Apr. 16	5	Apr. 21	5	May 8	17	49
Do	Apr. 6	17	Apr. 13	7	Apr. 17	4	Apr. 28	11	May 9	11	50
Mar. 21	Apr. 2	12	Apr. 8	6	Apr. 13	5	Apr. 20	7	...do	19	49
Mar. 20	Apr. 4	15	...do	4	...do	5	Apr. 29	16	May 11	12	52
Mar. 18	Mar. 30	12	Apr. 6	7	Apr. 11	5			...do		54
Mar. 10			Apr. 4		...do	7	Apr. 20	9	May 12	22	63
Mar. 20	Apr. 2	13	Apr. 6	4	Apr. 14	8	Apr. 24	10	May 15	21	56
Average[1]		13.2		9.5		6.4		8.2		13.8	50.1

[1] Total of averages of instars, 51.1 days.

TABLE IV.—*Length of nymphal stage of the sharp-headed grain leafhopper, Tempe, Ariz., 1914*—Continued.

SECOND GENERATION, MAY AND JUNE, 1914.

Nymph emerged from egg.	Date of first molt.	Length of first instar.	Date of second molt.	Length of second instar.	Date of third molt.	Length of third instar.	Date of fourth molt.	Length of fourth instar.	Date of fifth molt.	Length of fifth instar.	Total length of nymphal stage.
		Days.		*Days.*		*Days.*		*Days.*		*Days.*	*Days.*
May 15	May 21	6	May 26	5	May 31	5	June 7	6	.....	.....	.....
May 14	May 22	8	May 28	6	June 2	5	June 6	4	.....	.....	.....
May 18	May 25	7	...do.....	3	May 29	1	June 4	6	.....	.....	.....
May 16	May 22	5	May 23	2	May 28	5	June 1	4	June 7	6	22
May 15	May 21	6	May 26	5	May 29	3	June 2	4	June 8	6	22
May 14	May 18	4	May 25	7	June 1	7	.....	.....	.....	.....	.....
May 15	May 21	6	May 26	5	May 28	2	.....	.....	.....	.....	.....
Average [1]		6	.....	4.7	.....	4	.....	4.8	.....	6	22

THIRD GENERATION, JUNE AND JULY, 1914.

June 28	July 1	3	July 6	5	July 11	5	July 14	3	July 21	7	23
Do....	July 2	4	July 5	3	July 13	8	July 18	5	July 23	5	25
Do....	July 1	3	July 6	5	July 12	6	July 17	5	July 22	5	24
Do....	June 30	2	July 7	7	...do.....	5	July 15	3	July 26	5	22
Do....	July 1	3	July 4	3	July 8	4	July 13	5	July 19	6	21
Average [2]		3	.....	4.6	.....	5.6	.....	4.2	.....	5.6	23

FOURTH GENERATION, AUGUST, 1914.

Aug. 1	Aug. 4	3	Aug. 9	5	Aug. 12	3	Aug. 16	4	Aug. 20	4	19
Do....	Aug. 5	4	Aug. 10	5	...do.....	2	Aug. 17	5	Aug. 21	4	20
Do....	Aug. 3	2	Aug. 8	5	Aug. 13	5	Aug. 18	5	...do.....	3	20
Do....	...do.....	2	Aug. 7	4	Aug. 11	4	Aug. 16	5	Aug. 22	6	21
Do....	Aug. 4	3	Aug. 9	5	Aug. 13	4	Aug. 19	6	...do.....	3	21
Do....	Aug. 5	4	Aug. 8	3	Aug. 12	4	Aug. 18	6	...do.....	4	21
Average [3]		3	.....	4.5	.....	3.6	.....	5.1	.....	4	20.3

FIFTH GENERATION, SEPTEMBER, 1914.

Sept. 2 [4]	.....	.....	Sept. 9 [5]	.....	.....	.....	Sept. 18 [6]	.....	Sept. 28 [7]	.....	26

SIXTH GENERATION, OCTOBER AND NOVEMBER, 1914.

Oct. 6 [8]	Oct. 11 [9]	.....	Oct. 17 [9]	.....	Oct. 23 [9]	.....	Oct. 30	.....	Nov. 9	.....	34

[1] Total of averages of instars, 25.5 days.
[2] Total of averages of instars, 23 days.
[3] Total of averages of instars, 20.2 days.
[4] About 20 nymphs.
[5] Nymphs in second and third instars.
[6] Nymphs in fourth instar.
[7] Sixteen adults.
[8] About 15 nymphs.
[9] About this date.

From Table IV it will be seen that it took the nymphs of the fourth generation the shortest time for development and growth, being an average of 20 days from egg to last molt. While the lengths may vary from season to season and from year to year, it is evident that during the summer months nymphs develop in about half the time of those of the first spring generation.

From the notes made by Mr. Wildermuth at Tempe, Ariz., in 1913, for the first spring generation the average length of the nymphal stage during March and April is shown to be 40 days, a few days less than that obtained the following year by the writer. (Table V.)

TABLE V.—*Length of nymphal stage of the sharp-headed grain leafhopper, Tempe, Ariz., 1913.*

Nymphs emerged from egg.	Adults emerged from last nymphal molt.	Length of nymphal stage.
		Days.
Mar. 18	Apr. 20	33
Mar. 24	May 5	42
Mar. 27	do	39
Mar. 24	May 10	47
Average		40. 25

HIBERNATION AND WINTERING.

Prof. Osborn [1] states that "hibernation seems to occur in all stages from the egg to the adult, although the great majority must pass the winter in the egg stage." At Tempe, Ariz., the writer searched diligently during January, 1914, for all stages of the species but found only adults. No eggs were deposited in cages either in or out of doors until February 4. Dissections of adult females during January showed them to be full of immature eggs. An experiment was carried on in which young nymphs were submitted to a temperature of 35° F. for 18 hours, at the end of which all nymphs were dead, showing that it is improbable that young nymphs could ever withstand the winter. Mr. F. H. Gates, another assistant of the Bureau of Entomology at Tempe, reports having taken adults on a number of days during November and December, 1914, and January, 1915. On December 15 he took several nymphs which were probably in the fourth or fifth instar. From his observations it would seem that the nymphs which had attained the fourth or fifth instar by late fall might survive the winter, although up to December 15 there had been no really cold weather at Tempe, the minimum temperature recorded to that date having been 28° F. At Charleston, Mo., during November and December no eggs or nymphs could be found, while the adults were present and active on warm days. It seems safe, therefore, to assume that the species winters over principally in the adult stage throughout the Southern States and in all probability the same holds true throughout the country.

GENERAL ACTIVITIES OF THE ADULTS.

The adults are exceedingly quick of movement, and might well be described as restless. They are easily disturbed or frightened and

[1] Op. cit., p. 58.

jump at the slightest provocation. Because of this fact they are readily caught in the hopperdozer. A clump of tall grass was observed one day to be almost alive with adults, and although there was no wind and apparently nothing to disturb them, the adults suddenly hopped away, all at once. What caused the alarm was not determined. Adults, as well as nymphs, have the habit of dodging to the opposite side of a leaf or stem when approached by a foreign object. On days when there is a strong wind they remain in hiding close to the ground. They are most active during midday, and seldom may they be seen hopping about when dew is on the plants. As the sunlight recedes in the late afternoon they seek shelter under dried leaves and refuse, and at the base of the plant stems. While adults are most active on warm sunny days, during the intense heat of the summer they seek shade and damp places. From a series of observations it has been noted that they are more active on sunny than on cloudy days. Many adults, but not in such numbers as nymphs, can often be found feeding or resting on the same stem or leaf. They both rest and feed with head upward on the plant.

GENERAL ACTIVITIES OF THE NYMPHS.

Nymphs are even more active than adults, doing more running and dodging and less jumping about the plants. They seem to group themselves together; oftentimes 15 to 20 nymphs can be found on 1 square inch of leaf surface, and it is because of this that their feeding becomes injurious to the plant. Mr. Wildermuth has observed that the nymphs commence feeding immediately after hatching. The wind has a stronger effect upon the nymphs than upon the adults, and oftentimes a gust of wind will blow the nymphs several yards. They attempt to keep out of the wind by hiding but are rather easily blown from one plant to another, the throats of young corn plants making a favorite hiding place. When resting the first-instar nymph assumes a characteristic posture, carrying its abdomen slightly curled up and over. The nymphs are very sensitive to heat, and the direct rays of the sun for more than a minute or two on hot days will kill these young stages. Many times they have been observed to burst a bubble of excreta from the tip of their abdomen when disturbed or approached by a foreign object, and Mr. Wildermuth suggests that this may be a means of defense as it is in the case of nymphs of the three-cornered alfalfa hopper (*Stictocephala festina* Say).

OVIPOSITION.

A few days after the male and female adults have emerged from the last nymphal molt copulation has been noted to take place. In 10 experiments carried on in confinement the male died within 1 and 2 days after copulation, although the females, in the same experi-

ment, lived for several weeks after oviposition. The females which overwinter copulate in the fall and may not oviposit until the following spring. The time between copulation and oviposition during other seasons is much shorter, generally about 10 days. As to the manner of oviposition Mr. Wildermuth noted the following: "Her ovipositor was already inserted when found, and she remained so for 22 minutes, being first observed at 1.55 p. m. and withdrawing the same at 2.17 p. m. The angle was changed several times, however, as she inserted the eggs, 7 in all, through the same slit which was about 1 mm. in length. Of course there is no way of knowing how long she had been in the position when found." Females do not necessarily choose protected parts of a plant for oviposition. In all cases noted with grains and grasses the egg pockets were constructed under the epidermis of the upper or inner side of the leaf. Mr. George G. Ainslie noted in Florida that egg pockets in corn are usually to be found in the midribs of leaves and frequently in stalks. In one instance he found an egg slit in a stalk just below the tassel. Eggs within the pocket are placed in a close-fitting row, with their long axes parallel. The number of eggs deposited by a female varies somewhat, but in general it may be said that a single female is capable of depositing between 40 and 50 eggs. The number to a pocket also varies from 2 to 12, with an average of 5, as shown in Table VI.

TABLE VI.—*Oviposition of the sharp-headed grain leafhopper in various plants.*

Plant.	Total number of egg pockets.	Total number of eggs.	Average number of eggs in a pocket.[1]
Wheat	22	102	4.6
Barley	16	85	5.3
Oats	26	155	6
Alfalfa	16	94	5.8
Johnson grass	2	12	6

[1] General average 5.5.

From 18 egg pockets in corn leaves Mr. Ainslie found that the number of eggs per pocket varied from 4 to 20, with an average of 12. This is probably due to the fact that the epidermal tissue of corn leaves is more flexible, thus allowing the construction of larger egg pockets. The period of oviposition may extend over from one to three weeks. Oftentimes a female will construct three or four pockets in one leaf. There seems to be no preference between the different grains for oviposition; however, grains and other broad-leaved grasses, such as Johnson grass, are preferred to alfalfa.

HATCHING OF THE EGGS.

The emerging nymphs burst the end of the eggshell irregularly and emerge head first. Eggs deposited in the leaves hatch sooner than those in stems, as there is not so much plant tissue covering them. Those in stems appear to be inserted more deeply into the plant. The nymphs issue at about the same time, irrespective of the position of the eggs in the pocket.

MOLTING OF THE NYMPHS.

The fourth molting of a nymph was minutely observed, the whole operation taking 20 minutes. The old skin split dorsally along the head and thorax. The head of the nymph first came out, slowly followed by the thorax and abdomen. The abdomen was pulled forward through the old abdominal skin and put through the thoracic slit. As the nymph gradually emerged it leaned or threw its weight backward until the tip of its abdomen was nearly out; then it shifted and spread its legs, taking a firm hold on the leaf surface. After completing the molt it remained still for several minutes.

In examining the last-molt nymphal skin an indication of sex was discovered. Outlines of the ovipositor or genitalia were quite prominent and plain on this cast skin. Attention was then directed to the examination of the last-instar nymphs, and it was found that there is a sex indication with all nymphs of the fifth instar, as the distinction between the male and female genitalia could readily be recognized. (See fig. 1, *i*, *j*.) No sex indications appear in the nymphs of the fourth instar.

ADAPTABILITY OF SPECIES TO CHANGE OF FOOD PLANT.

Only the nymphs of the last two instars can adapt themselves to a change of food plants to any extent. This fact offers a suggestion in the control of the species, in that cutting or grazing their food at the time the nymphs are young will tend to starve them, and thus many will be destroyed.

However, the adults find no difficulty at all in a change. If their food plants be destroyed or cut down, they immediately hunt for substitutes. Starving the adults in the fields would be next to impossible.

MIGRATION.

The species does not spread itself throughout one field or into other fields by the dissemination of the young nymphs, but almost wholly by the flight of the adults. The latter migrate freely from one field to another in search of attractive areas for food and oviposition. Besides this, Prof. Osborn remarks:[1] "The insect shows at times a distinct habit of migration at night." They have been reported

[1] Op. cit., p. 59.

around Columbia, Mo., "in such numbers that they could be gathered up by the bushel."[1] Strong winds in midsummer no doubt are responsible in many cases for what may seem a natural migration.

ENEMIES.

PARASITES.

Probably the most effective enemies of the sharp-headed grain leafhopper are its egg parasites, two species of which were reared in great numbers during the summer of 1914, while the writer was stationed at Tempe, Ariz. Both of these egg parasites were new to science, and Mr. J. C. Crawford[2] has described one as *Gonatocerus gibsoni;* the other Mr. A. A. Girault will describe as *Abbella auriscutellum.* Had it not been for these two egg parasites considerable damage would probably have been done by the jassid during the summer months. One of these parasites, *Gonatocerus gibsoni,* not only held the species in check but practically eradicated the pest in the Salt River Valley of Arizona. In this valley there was from 75 to 95 per cent of parasitism among the eggs of the second generation of the grain jassid between May 15 and June 15. Mr. J. H. Newton, a temporary assistant in the Bureau of Entomology at Tempe, found an 85 per cent parasitism from several hundred egg pockets examined.

Mr. George G. Ainslie, while in Florida during the spring of 1914, reared two species of egg parasites; one of these, reared in considerable numbers, has been determined by Mr. Gahan as *Brachistella acuminata* Ashm. Mr. Ainslie recorded a 79 per cent parasitism among eggs examined. Mr. R. A. Vickery reports having reared many parasites of *Ufens niger* Ashm., as determined by Girault. Five or six were reared from each egg.

There are many parasites which affect the Jassidæ and it is quite likely that this species comes in for its share. Although none has been recorded as having been reared from the grain leafhopper, yet in all probability some of the members of the families Proctotrypidæ and Dryinidæ materially help in suppressing its numbers. Several adults of *Athysanus exitiosus* Uhl. were taken which were parasitized by one of the Proctotrypidæ which appeared in the form of an external sacklike structure within which the parasite sucked the juices from the abdomen of the host. These adults of *A. exitiosus* were swept from fields where the grain jassid was very numerous. In the report of the Hawaiian entomologist and in the papers of Perkins and others may be found accounts of various parasites of the Jassidæ. The dipterous genus Pipunculus contains parasites of leafhoppers and according to Giard they are parasitic especially upon the family Jassidæ. The order Strepsiptera (the twisted-wing insects) contains

[1] Op. cit., p. 20.

[2] Crawford, J. C. Descriptions of new Hymenoptera, No. 9. *In* Proc. U. S. Nat. Mus., v. 48, pp. 577–586, sep. no. 2087, May 3, 1915. *Gonatocerus gibsoni,* new species, p. 586.

parasites upon jassids, but whether or not they have been reared from this species the writer does not know.

ENEMIES OTHER THAN PARASITES.

It is a common sight to see jassids caught in spider webs. Several adults and nymphs of *D. mollipes* have quite frequently been observed in webs, and in more than one instance the writer has seen spiders [1] carrying off dead adults. In Bulletin 108 of the Bureau of Entomology is an account of *Reduviolus ferus* L. as a predaceous enemy of leafhoppers. During the past summer the author observed on two occasions the large agricultural ant (*Pogonomyrmex barbatus* Smith) dragging off an adult grain jassid. Turkeys and toads have been observed catching and eating the adults in alfalfa fields. Prof. Osborn [2] gives a list of over 100 birds whose crops have been examined and found to contain jassids.

FUNGUS.

Prof. Osborn makes mention [3] of a fungus, *Empusa grylli*, which causes an epidemic disease affecting this species. The occurrence of this fungus has been recorded also by Prof. F. M. Webster and Prof. H. Garman.

REMEDIAL MEASURES.

From a study of the habits of this jassid certain simple preventive measures present themselves. In the Salt River Valley of Arizona and in localities of similar conditions the keeping down of wild grasses, principally Johnson grass, along irrigation ditch banks, fence rows, and along roadsides during the summer months will do much in preventing the species from spreading and increasing in numbers. By cutting down or grazing sheep upon these broad-leaved grasses, which afford the preferred summer food, their summer breeding places will be destroyed and an immediate check upon the species produced.

As soon as possible after the grains are harvested the ground should be broken up and planted. If immediate planting is not practical, then the ground should be broken again by either replowing or harrowing after two or three weeks to keep down all native grasses and weeds.

Quoting from Osborn: "The direct treatment which has had the most thorough trial is the use of the hopperdozer, which consists of a sheet-iron strip coated with coal tar. The apparatus is drawn over the grass and the insects, hopping at its approach, fall upon the surface, and thus many are killed." [4] The hopperdozer can be used to advantage while the grain is young and short. It should be used

[1] A list of spiders which feed upon leafhoppers may be found in Bulletin No. 108 of the Bureau of Entomology, U. S. Department of Agriculture, page 35.
[2] Op. cit., p. 28–31.
[3] Op. cit., p. 57.
[4] Op. cit., p. 37.

during the heat of the day when the leafhoppers are most active and jump at the least provocation.

Where the species is infesting pastures or grass lands close pasturing or cutting while it is in the egg stage is advised. Especially would this prove beneficial in the Northern States where the length of the egg stage covers several weeks. So far as the observations of the author go it would appear useless to burn grass for the destruction of the eggs, as when the leaves and stems wither or dry up the eggs do not hatch. Seemingly the eggs must have the moisture of at least the surrounding tissue for hatching. However, the burning of the grasses in which the species may be hibernating in the Northern States would no doubt destroy many of the adults.

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BULLETIN No. 255

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER July 22, 1915.

DOUGLAS FIR PITCH MOTH.[1]

By JOSEF BRUNNER,
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NATURE AND CAUSE OF DAMAGE.

Pitch seams, gum check, windshake, or whatever these defects may be termed locally, have ever been recognized as a serious depreciating factor in the utilization of Douglas fir (*Pseudotsuga taxifolia*). These defects have heretofore been variously charged to windshake (mechanical strain), lightning, frost, blazes, fires, and various other unavoidable causes, but investigation of the trouble and its causes makes it evident that the work of the larvæ of the Douglas fir pitch moth (*Sesia novaroensis* Hy. Edw.) is the primary cause of a large percentage of these defects.

DISTRIBUTION AND EXTENT OF DAMAGE.

In the northern Rocky Mountain and Pacific coast regions it has been definitely determined that the Douglas fir pitch moth is responsible for at least 90 per cent of this damage.

A very similar larva,[2] found working in Douglas fir in the southern Rocky Mountain district, makes it quite certain that the same species is responsible for what similar depreciation in timber value may be existing there.

The loss occasioned by the work of this class of insects causes the difference in price between absolutely clear lumber and the lower grades or "dimension stuff." These insects work in the portion of the trunk which later clears itself of branches; hence only logs are affected which, were it not for previous infestation by them, would yield only the better grades of lumber.

Extensive correspondence with mill managers in various parts of the northern Rocky Mountains and Pacific coast range has elicted the fact that no accurate record is kept of the extent of the prevalence

[1] *Sesia novaroensis* Hy. Edw.; order Lepidoptera, family Sesiidæ. Identification by Mr. August Busck.

[2] The insect from the southern Rocky Mountains, after the rearing of three specimens, proves to be *Sesia novaroensis*.

NOTE.—This bulletin is of interest to entomologists as a contribution to their specialty, and to owners and manufacturers as a business proposition.

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of pitch seams in the logs used. But all Douglas fir sawyers estimated a general loss in the entire Douglas fir product of between 7.5 and 15 per cent due to this defect. The depreciation is lowest in the Rocky Mountain region and heaviest toward the coast, evidently corresponding to the respectively slower or quicker growth of the trees in the respective localities and to the relative scarcity or abundance of the moth in these regions.

The writer and his field assistants made a thorough investigation of the logs in the woods and during the sawing of them in the mill, from the manager of which the estimate of lowest loss was received. This mill cuts usually not less than 25,000,000 board feet annually, but the cut during the season 1913–14 was only 14,000,000 board feet. This investigation showed that from 15 to 25 per cent of all the logs in the 14,000,000 board feet had been damaged by the moth. Of the logs clean of branches, in which this sort of damage mainly prevails, fully two-thirds were depreciated in this manner, notwithstanding the fact that those from exposed localities, which are unfavorable to the insect, were practically free from the defect.

The results of the investigation were taken up with the mill manager and it was agreed that the loss in this case constituted but 5 per cent. Yet even this low percentage represented, at the selling price of the lumber at the mill, a loss for that season's low cut of $18,900 to that firm alone. While this percentage is evidently much below the average, it is indicative of what this leak probably means to mills in the entire range of the Douglas fir.

MANUFACTURERS[1] BEAR THE LOSS.

At the present selling price the loss is almost entirely borne by the manufacturer. In the absence of the depreciation, consumers could get the best grades of lumber for the prices they now pay for the cheaper grades, and the manufacturers would besides be able to make a larger clear profit, as they would not have to handle the inferior material from the stump to the lumberyard. There is no help for the lumber now being cut, but the defect is avoidable in the future timber supply. There seems to be no reason, therefore, why the cause should not be eliminated and why mills and lumber consumers should be taxed forever by an insect the work of which involves such extensive financial waste.

SCOPE OF THE INVESTIGATION.

Evidently nothing was known in regard to the larval stages and activities of this insect until the spring of 1913, when, under assignment from Dr. A. D. Hopkins, the writer undertook a systematic study of

[1] By the term "manufacturer" is meant the "saw-mill" man, and by the term "consumer" is meant "contractor, buyer, and builder." A. D. H.

the seasonal history and habits of insects affecting the growth and development of trees, though a number of caterpillars, of what later proved to be this moth, had been caged during the autumn of 1912 for observation. Active cooperation in collecting larvæ and field notes with Messrs. Edmonston, Miller, Burke, Harvey, and all the entomological rangers assigned to the various western field stations from April, 1913, until late autumn, 1914, made it possible to determine not only the insect's distribution, but its comparative abundance and destructiveness in widely separated regions of the Douglas-fir range and also to make this investigation pretty thorough west from the eastern boundary of the State of Montana, toward the coast, and north of latitude 41° 30′ to the boundary of the United States.

LIFE HISTORY.

THE ADULT.

The Douglas-fir pitch moth, like all the members of the Sesiidæ, much resembles, in general appearance, certain wasps and flies. This resemblance is especially strong when the insect is in flight.

The ground color of the insect is black, with rich orange-red spots on the thorax and with all the segments, except the last, banded with the same color. Underneath the whole insect is rich orange-red. Aberrations in color are not frequent but exist, as the rearing of a wholly black female would indicate.

The forewings are transparent, opalescent, with black borders and prominent discal mark; the hind wings transparent, with slight discal mark and narrow black margin. The spread of wings is from 30 to 35 mm., about the size of an ordinary "yellow jacket." The male is about one-third smaller than the female and more slender.

THE EGG.

The eggs are brownish, slightly oblong, and are laid singly. A single female appears to produce slightly in excess of 30 eggs, the issue from two specimens being 34 and 37, respectively. In the field their incubation period is about two weeks.

THE LARVA.

With the exception of the head, which is dark brown, the larva (fig. 1) is white; through the transparent skin the darker intestines and their contents are plainly visible, thus making this larva readily distinguishable from that of *Vespamima sequoia* Hy. Edw., which, to a slight extent, also infests Douglas fir, but which is more robust, has a denser skin, and is dirty white. Especially is this internal dark spot a feature in 1 and 2 year old larvæ, although it is retained to a marked

degree until pupation, which takes place in the third season after the deposition of the egg.

The head is small and rounded; the body cylindrical, rather slender in comparison with that of the larvæ of other sesiids. When full grown it is from 1 to 1½ inches long.

THE PUPA.

The pupa is shining brown, armed with transverse rows of spines on the back of the abdominal segments, by aid of which it moves back and forth at will in the tunnel made by the larva before pupation in the covering pitch mass. When ready for the final transformation the pupa uses these spines for working its way through the thin layer of pitch at the mouth of the tunnel, by projecting its anterior segments to at least one-half of the entire pupal length through the opening, and holding itself securely during the escape of the moth.

SEASONAL HISTORY.

The pupal period as observed in the laboratory is 30 days, but under adverse weather conditions it seems to be prolonged a few days. Usually moths appear in greatest numbers the first sunny day after a rainy spell.

The general emergence of the Douglas fir pitch moth occurs during the month of June, although individuals emerge in Montana as early as May 15, and farther west adults may be found by the first of that month. On May 20 the writer noted the first female (no male was observed at large during two years of observation) flying up and down a Douglas fir tree, evidently in the endeavor to locate a favorable spot for oviposition. Fresh empty pupal shells were observed protruding from pitch tubes on infested trees as early as May 15. A living chrysalis was found early in April, which, allowing 30 days for pupation, would evidently result in adults appearing early in May. It is rather striking that most of the early chrysalids were found at the highest altitudes in which the moth is active. This makes it probable that the shortened seasons at high altitudes are frequently responsible for an extension of the larval period into the fourth year, just as, in consequence of late August oviposition at lower altitudes, a certain percentage of the insects do not attain maturity during the three years that this species requires for development from egg to adult. In such instances the larva pupates during the first warm days of the fourth season. Occasionally adults emerge up to the last of July and the first part of August.

The mature insect lives only about five days after emerging from the pupa, which accounts for its scarcity. Even where its work

proves that it is fairly numerous, it is only by good fortune that one gets a chance to observe its behavior. During two seasons of judiciously chosen days and locations for observations the writer saw but six specimens in the forest. They were all females, and each of them was apparently engaged in oviposition. While the insect swiftly wings its way up and down the tree trunk, the eggs are deposited, either at the edge of a wound or a perfectly smooth spot, oftener the latter, and only a single egg is deposited at each place.

In Montana, where the insect is not exceedingly numerous, the writer and Entomological Rangers Swartz, Wagner, and Fleming examined hundreds of trees, each of which displayed comparatively fresh, healed-over wounds, unquestionably of sesiid origin, but in no case was more than one larva of each of the triennial generations found at the same time in the same tree. This suggests that if there is an abundance of suitable trees for infestation a female, after depositing one egg only on a tree, leaves the latter, repeating the same operation until its supply of eggs is exhausted. Consequently quite a number of trees are thus affected by a single female.

FIG. 1.—Three generations of larvæ of the Douglas fir pitch moth (*Sesia novaroensis*). Natural size. (Original.)

From Ashland, Oreg., where the insect is much more abundant than in the Rocky Mountains, Mr. Edmonston reported as many as 6 larvæ, all of which proved to be of the same generation, from a single tree, and Mr. B. T. Harvey states that quite a number of trees in the coastal region are scarred from base to near the tops by the work of this moth.

I have no doubt that this apparent discrepancy in ovipositing is due solely to the fact that in regions where the insect is nearly ten times as numerous as in the Rocky Mountains several females by chance deposit eggs upon the same tree; in fact, they are compelled to do so, unless they are willing to oviposit on trees that are undesirable on account of growth.

By August 1 young larvæ from the June oviposition, upon close examination of the infested trees, may be readily located by the boring dust, which resembles that of *Dendroctonus pseudotsugae* Hopk. This dust is produced by the larva eating its way through the outer bark into the cambium. At the end of the first active season a pitch tube covers the wound as well as the larva which made it.

During the second season the larva merely maintains and enlarges the established chamber or tunnel, and, growing in size, as far as was possible to ascertain, molts the first time when 1 year old. The third season is passed like the second, the larva molting once again when two years old. By the end of this period the covering pitch tube is about the size of a silver dollar, depending somewhat on the shape of the wound inside.

The third spring after deposition of the eggs the larva, now nearly three years old, is ready to pupate. During the last two years the larva changes but little in size; the younger is somewhat more slender if of the same length as the older. The older larva, however, has become so thick skinned that it appears almost entirely white, while through the thinner skin of the younger generation the reddish intestines are still plainly visible. It is not a simple matter and requires a great deal of experience to separate these two generations.

With the exceptions noted for high altitudes and late oviposition, exactly three years after the egg was laid the adult appears, completing the life cycle and making the generation of the species triennial.

Although there are no seasons in which this insect is very abundant there are none in which it is unusually scarce.

HABITAT.

Unlike others of this group of insects, the Douglas fir pitch moth prefers the shade. It is most numerous in from 10 to 50 year-old Douglas-fir stands with a northerly exposure, and is consequently most injurious there. So-called "spruce swamps" are as much avoided as are the sun-exposed hillsides. While it may also be found to some extent on sunny slopes having a stand of trees sufficiently dense to provide practically constant shade, it is usually only trees which have been injured by some other cause which are here infested first. The insect is evidently attracted here from the preferred localities by the smell of pitch, just as barkbeetles are attracted by the smell of felled or fire-scorched timber.

It may be noted here that larvæ under pitch tubes which are much exposed to the sun are almost invariably killed during the winter months. Evidently the larva can not survive when kept active by the warmth of the sun while its sustenance is cut off by frost. This may probably explain why this insect is not numerous under conditions which expose it much to the influence of the sun. The pitch tubes of *Sesia novaroensis* and the bark of Douglas fir at the usual points of infestation do not provide the protection against the indicated influence as do, for example, the big pitch tubes and the bark of yellow pine for the larvæ of *Vespamima sequoia*, which survive under any exposure, presumably on account of this protection.

LOCATION OF AFFECTED AREAS.

The Douglas fir pitch moth has apparently a very marked habit concerning the preferred areas in given localities. An area in which it is depreciating the timber now may be readily located by simply watching the logs at the mill as they go through the saw and ascertaining where those with pitch seams come from. It may seem a matter of speculation to undertake to determine localities where the insect is numerous at present by thus examining trees which have been infested a century or more in the past, but it has been ascertained to be an absolutely reliable method. The success of this test not only proves that the sesiid is the cause of the depreciation, but it shows us in addition how we may determine the exact localities where the merchantable timber is liable to serious damage by the insect, because wherever the injury exists in the young, growing timber, which will be "loggable" a hundred years from now, it is practically certain that the mature trees had been afflicted in the same manner in their youth.

RANGE OF THE INSECT.

As already indicated, the range of this insect is over the northern Rocky Mountain and Pacific Coast regions and extends in all probability through the entire native range of the Douglas fir. From my own observations and numerous field notes and from larvæ collected in various parts between the northern boundary of the United States and latitude 41° 30′ N. and from the eastern boundary of the State of Montana to the western coast by other members of the Branch of Forest Insects and kindly put at the disposal of the writer, it is evident that the moth is most abundant in the western part of its range, a conclusion which in turn is verified by the losses estimated by millmen in the various sections of this area.

HOST TREES AND CHARACTER OF INJURY.

(Figs. 2–5.)

Douglas fir (*Pseudotsuga taxifolia*) is evidently the special host of this moth. However, although unable successfully to attack previously uninjured larch (*Larix occidentalis*) it breeds also and thrives well in blazes and other wounds on that tree, particularly in the pitch flow caused by a fungus, identified by Dr. James R. Weir, of the Bureau of Plant Industry, as *Trametes pini*. A great number of fungus-infested larch in a stand of timber may make this tree a real menace to the Douglas fir in the same area.

The healthier and quicker growing a Douglas fir may be, the more it appears to be subject to infestation by the moth. Trees are attacked when about 10 years old and after that until they are about

50 years old, when the bark has roughened and thickened to an extent to render it practically immune. However, on many trees the bark over previous sesiid wounds is frequently in a condition which invites reinfestation, and thus larvæ are often found in trees which are ready for logging. Especially is the latter a frequent occurrence, if, as a result of the circular pitch seam inside, caused by the moth many years ago, the tree is split by wind strain from that seam straight to the surface of the bark. Toward the end of the first-year work of the larvæ, usually about August, the effect of

FIG. 2.—Work of the Douglas fir pitch moth: Evolution of pitch blister and pitch seam. (Original.)

their presence is shown in the growth of the new layer of wood, which is restricted immediately above and below and to some extent on the sides of the wound. Pitch formation in this new layer of wood and in the underlying layers, in an attempt by the tree to protect itself, forms the nucleus of the pitch blister. The inflexibility of this blister, even if the timber is but normally swayed by the winds as the tree grows taller, is bound to cause a further parting of the tissues and ultimately results in the pitch seam, which so greatly depreciates the value of the logs as lumber material. The afflicted tree endeavors, during the three years required by the larva to develop to adult, to wall up the wound, and the larva tries to maintain its established position; this struggle results in the wound

becoming rather deeply embedded in the woody tissue. From then on it depends upon the growth of the tree whether only the pitch blister at the base of the wound is to be inclosed in the healthy tissues or whether the pitch from the pitch tube and bark also is to be inclosed. As a rule, a tree of slow growth heals from the inside and the injury is less apparent, whereas a tree of rapid growth puts forth such a quantity of new growth over the injured spot that clean healing is impossible and a serious defect is evident almost immediately,

FIG. 3.—Work of the Douglas fir pitch moth: Effect of infestation on the wood growth 2 inches below (and above) the wound the first year after attack. (Original.)

even without the added aggravation of mechanical wind strain. The effect of mechanical strain during succeeding seasons upon trees afflicted with serious wounds from the very beginning renders them unfit as lumber material.

The real depreciation of the future saw log is inflicted while the trees are less than 50 years old, and most of the pitch seams, which result more or less in a separation of the inner and outer tissues, are caused by the insect when the trees are quite young. While the

original wounds made by individual specimens may be several feet apart on the trunk of a tree, as the latter grows taller and is swayed by the wind the inflexible blisters are gradually lengthened and widened and finally united. In trees which had been infested on all sides the seams are entirely circular, while in those infested on one

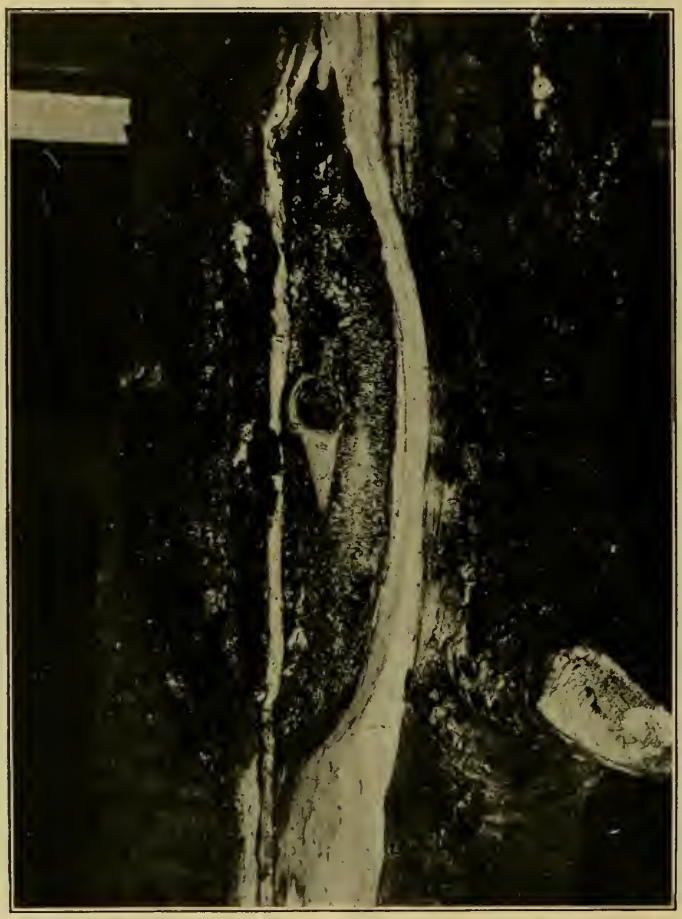

FIG. 4.—Work of the Douglas fir pitch moth: Pitch blister two years after emergence of moth, with tissues which had already grown over it perfectly, removed at one side. Natural size. (Original.)

side only, a frequent occurrence, the seam is semicircular. However, the cause which underlies both these effects is the same.

EVIDENCE THAT IT IS INSECT WORK.

(Figs. 6–8.)

Full-blown pitch seams probably never pass into lumber, and affected parts of logs are either converted into small "dimensions,"

laths, or firewood. Therefore to illustrate them adequately it would be necessary to split tree trunks, often for the length of several logs, to show a side view of an entire seam, and even if this were accomplished successfully the result would be merely something like a board which had been split and had been loosely stuck together again. With the exception of figure 2, showing the evolution of

FIG. 5.—Wound caused by the Douglas fir pitch moth. Photographed soon after emergence of moth. Natural size. (Original.)

the pitch seam, the photographs used to illustrate the injury to Douglas fir by pitch-moth infestation are from material from which the insect emerged so recently that the cause of the wounds is obvious. Such injury within the tissues of a coniferous tree is never eliminated in the course of years, but rather becomes accentuated when the split of the tissues is later extended for the length of many feet by mechanical strain.

WINDSHAKE AND LIGHTNING NOT THE CAUSE OF PITCH SEAMS.

The contention that windshake is capable of causing pitch seams in perfect tissues of this tree is not tenable when the facts at hand are considered. If this were true, freely exposed trees should contain the greater number of pitch seams, and those in sheltered positions should have few or none, which is not the case. Also, Douglas

FIG. 6.—A cross-cut showing wound caused in a young tree by the larvæ of the Douglas fir pitch moth. Reduced. (Original.)

fir is generally recognized to be of more tenacious fiber than larch, as is frequently illustrated in timber-sale contracts, which provide for the "butting" of the latter trees over a certain size, on account of depreciation in that part of the tree by "genuine windshake." To the knowledge of the author timber-sale contracts contain no such clause or even a similar clause concerning Douglas fir. While in the larch, recognized to be subject to windshake, owing to brittleness, the damage by windshake extends but a few feet above the base, in the admittedly tougher Douglas fir the damage from supposed "windshake" frequently runs up to 60 and more feet. "Wind-

shake" in larch above a few feet from the ground is practically nonexistent, since this tree, more than any of our conifers, is, if healthy, immune to insect attack, except to the foliage, and, if attacked, is more able to repulse the onslaught from the outset.

"Lightning" has been included in the same category with "windshake" as a cause of pitch seams in Douglas fir. The theory that lightning is a causative agent refutes itself by mere examination of the damaged material. It is the lower two-thirds of the tree trunks which are seriously pitch seamed, while the upper part is almost invariably free from the defect, and it is not reasonable to assume

FIG. 7.—Development of a "pitch seam" only four years after the emergence of the Douglas fir pitch moth. Note the enormous growth the tree put forth to cover the wound. Greatly reduced. (Original.)

that the electric spark would persistently leave the tops untouched and so frequently injure only the part below the branches.

Another point in this regard is the fact that judging from the location of the seams in the trunks the trees could not have been of very great size when the defect occurred. A casual stroll in the woods will convince the most heedless observer that it is not the younger trees which are most subject to lightning.

It is evident from the foregoing that infestation of a tree by the Douglas fir pitch moth does not result in immediate financial loss.

This has to be borne by future generations, just as the present is paying for the damage inflicted by the insect a century or more in the past.

Actual tally of sesiid wounds, blazes, bullet wounds, bruises by blasting, etc., all of which cause blister effects in wood tissue, was

FIG. 8.—An embryo pitch seam caused by the Douglas fir pitch moth only a few years after emergence of moth: *A*, Pitch blister which the larvæ caused before emerging; *B*, a break in the tissues by wind strain on account of the defect; *C*, break filling with pitch; *D*, inclosed pitch from pitch tube which caused imperfect healing; *E*, parts of pitch tube which covered the larvæ, still part of the surface covering. Reduced. (Original.)

made in a stand of Douglas fir about 30 years old, where conditions were most favorable for the operation of all the latter causes. This tally demonstrated that in this area of about 30 acres the sesiid wounds averaged, up to 15 feet from the ground, a little over 96 per cent, while the wounds from all other causes combined represented less than 4 per cent. Wounds above 15 feet could safely be consid-

ered almost entirely due to moths, but they were not counted. If they had been counted the percentage of all other factors would not have exceeded 1 per cent, and this in a location more or less unfavorable for the moth.

CHARACTER OF LARVAL WORK.

(Figs. 9–10.)

If trees have been injured the eggs are evidently deposited by the moth at the edge of wounds, regardless of their origin, and the larva

FIG. 9.—Tunnel at the end of the first active season of the larvæ of the Douglas fir pitch moth. Natural size. (Original.)

begins feeding at such places. The larva apparently follows the line of least resistance, because the resulting tunnel is likely to assume any shape in such cases. On perfectly sound trees the egg is evidently deposited where the bark is absolutely smooth and fresh, and the larva feeds upon the bark as soon as it slips out of the eggshell. This is apparently also the reason why trees with thick bark are attacked only where sesiid or other partially healed wounds provide conditions which answer the same requirement.

After the young larva has penetrated to the cambium, which usually occurs about August, or at a time when the growing period of the tree for the season is ended, it excavates a tortuous tunnel from 1 to 2 inches in length, parallel with and transverse to the grain of the wood. The length of the tunnel at completion depends largely upon the growth of the infested tree. In slow-growing trees

FIG. 10.—Pitch tube covering larvæ of the Douglas fir pitch moth the second year after infestation. Natural size. (Original.)

it reaches occasionally a length of from 5 to 6 inches at the time of moth emergence, while in very vigorous growers the larva maintains its well-being within a circular-shaped pit, not more than 2 inches in width, deeply embedded in the woody tissues of the cambium.

The surface of the wound is invariably covered by a pitch tube of the color of the bark. When the outer crust of the tube is removed it is found to contain pitch and the excreta of the larva. If the same wound is reinfested, soft pitch mixed with the old crusty pitch

usually indicates the presence of the larva. Plural infestation under one pitch tube has not as yet been observed.

It is only upon very close examination of the tree that the infestation will be revealed, so perfect is the blending of color of the Douglas-fir pitch and the bark, notwithstanding the fact that the covering pitch tubes are about 2 inches in diameter and protrude at least 1 inch from the surface of the bark. The protuberances so much resemble a knobby growth that considerable experience is necessary to enable one to distinguish them at sight.

The attack is restricted to the main trunks of trees, the first, second, third, and fourth logs being usually most affected, the injury becoming notably absent above 60 feet from the ground.

Trees are never killed outright, although very vigorous trees, if attacked several seasons in succession, become so weakened that their originally less robust neighbors easily outgrow them.

RELATION TO OTHER DESTRUCTIVE INSECTS.

In most localities where the Douglas fir pitch moth is present Douglas fir and larch trees are to be found with dead bark on the trunks in strips several inches wide and often more than 20 feet long. This peculiar injury, except in the case of Tetropium in larch, is usually attributable primarily to fires, bruises by falling trees, and perhaps, to some extent, lightning. Examination of these strips under the bark usually reveals sesiid larvæ, or at least abundant traces of their work. The galleries under the bark contain, in addition, the unmistakable evidence of beetle infestation. In all such cases coming under the writer's observation these beetles of the genera Melanophila or Tetropium were found to have infested the trees primarily or after they had sustained the mechanical injuries before mentioned, and to have been the agents which prepared favorable propagating places for the moth. Extended observations lead the writer to believe that these and similar beetles do not follow the moth, but that the moths occasionally adopt the galleries, etc., of the beetles.

A few trees which had been outstripped by their companions, evidently on account of previous moth infestation, were noted as subsequently killed by *Scolytus unispinosus*, but, considering that these trees when killed by the beetles were already worthless as timber producers, the interrelation of moth and beetle in this instance seems of no economic consequence.

Vespamima sequoia[1] is another very injurious pitch moth which infests Douglas fir in old wounds and branches, and especially wounds

[1] Brunner, Josef, The Sequoia pitch moth. U. S. Dept. Agr., Bul. 111, 11 p., 5 fig., July 11, 1914.

originally made by *Sesia novaroensis*, thus extending the injury. In Montana it infests wounds in the trunks of Douglas fir to the extent of about 1 per cent. But in the vicinity of Ashland, Oreg., Vespamima appears to have developed a special liking for this tree. Fully 10 per cent of the pitch-moth larvæ sent me by Messrs. Edmonston and Miller from Ashland proved to be *Vespamima sequoia*. According to the accompanying notes, all of the larvæ of this species were collected in wounds previously made. At Placerville, Cal., a single larva of Vespamima was collected in Douglas fir, and this was in an old wound.

Wounds in Douglas fir, especially those made by the pitch moth, presumably on account of their better protective character, are usually infested for several seasons by the larvæ of a small moth of the genus Laspeyresia.[1] Two or three larvæ are frequently found around the edges of a single wound. The Laspeyresia also attacks young Douglas fir at the base of branches independently, and, although the attack itself usually does no permanent injury, the resulting accessibility to the cambium often induces infestation by the Sesia. That the work of Sesia is responsible for the increasing numbers of Laspeyresia, by providing favorable conditions for propagation, seems a reasonable conclusion, yet it is doubtful if the abundance or scarcity of Laspeyresia similarly affects the pitch moth, which is well able to establish and sustain itself.

RELATION TO NATURAL ENEMIES.

In localities where *Sesia novaroensis* is more than commonly numerous nearly 20 per cent of its larvæ are killed before reaching maturity by a tachinid parasite.[2] The influence of this parasite as a check on the numbers of Sesia or as lessening the depreciation of timber appears from a strictly economic standpoint to be practically nothing, since it appears from extensive observations that only those moth larvæ under imperfect pitch tubes are subject to attack by the parasite. As the greater number of pitch tubes form an impenetrable barrier against the parasite, there is little reason to expect that it will ever be a factor in the control of the pitch moth.

MEANS OF CONTROL.

In determining control measures for use against the Douglas fir pitch moth five readily accessible areas were selected for detailed investigations. On all of these the stand of timber was mixed and the conditions were those which obtain in almost any location west of the Rocky Mountains, excepting the pure pine stands. The results

[1] Identification by August Busck, Bureau of Entomology.
[2] Identification by C. T. Greene, Bureau of Entomology.

of the investigations and experiments (Table I) made it evident that to accomplish any permanent good under general forest conditions it is best to extend control over large areas. In Project III, for example, where the infestation is in general rather slight, collecting was done within a 5-section limit over 460 acres only, in strips containing a stand of trees of a character more susceptible to attack, and while the destruction of the larvæ resulted in some reduction of the annual infestation, it could not in any sense be regarded as an important factor in reducing the ultimate depreciation of the timber without the application of constant attention.

TABLE I.—*Control of the Douglas fir pitch moth: Projects and results.*

Project No.	Damage.	Sections.	Acres.	Larvæ collected.		Remarks.
				1913	1914	
I	Medium...	5	3,200	790	74	To June; from August to December, 8 larvæ found in area. Collected thoroughly.
II	Serious....	.....	30	101	5	Thorough search.
III	Slight.....	5	460	94	53	From 1913 oviposition.
					16	From 1914 oviposition. Collected during December. Collecting done in strips of reproduction within the mature stand.
IV	Heavy....	.....	40	207	9	From 1913 oviposition.
V	Serious....	.....	10	41	2	From 1912 oviposition.

Project No.	Age of stand.	Local conditions.
	Years.	
I	10–40.....	Surrounded by older stand; hills and flats alternating.
II	30.....	Northern exposure; practically isolated, except for adjoining stand of mature timber.
III	120, with strips of reproduction from 10 to 40 years old.	Heavy mountain forest in a solid stand which extends for miles.
IV	40.....	Creek bottom; flat surrounded by steep hills stocked with 10-year-old and younger reproduction.
V	15–20.....	Practically isolated, being surrounded by yellow-pine stand free of any sesid.

In Project I, which also covers five sections, the larvæ were destroyed throughout, and during the autumn of 1914 but 8 larvæ were found near the border of the area. In Project I a daily inspection at the proper period in the year along the border would be amply sufficient to protect the entire area from a serious infestation until such time as the trees shall have outgrown the danger stage.

The principle of "isolating" stands susceptible to infestation should be the potent factor in control of this insect. Let us take a practical example of what is meant by isolation in this regard. Two streams, distant from each other in an air line say a couple of miles, run parallel from their source at the base of a mountain to the open farm lands, but between them is, as usual, a dividing ridge. Along both streams, in favorable locations, the moth is equally numerous, yet elimination of the moth along the entire length of one stream

means the practical dissociation of it from its neighbor, because the dividing watershed line invariably provides unfavorable conditions for moth existence on one slope. (See Habitat, p. 6.) No matter in which direction a stream may flow, one slope of the watershed is always subject to a greater degree of sunlight than is favorable to this insect. Again, a sufficiently wide strip of trees other than Douglas fir on the opposite side of a stream may safely be regarded as a buffer, as was indicated in the results of investigations in Projects II, IV, and V. Project V was an almost pure stand of Douglas fir which was connected with the next nearest solid block of Douglas fir, about 1 mile distant, by a few stragglers of this fir through the solid stand of surrounding yellow pine.

Small tracts, which can be given attention for a few days annually, may be kept comparatively free of infestation and, even if infested, the removal of the larva during the first year of its life will prevent the development of the wound to the serious stage. Of course the infestation, even for only a year or less, will leave a pitch spot in the tissue, just as is produced in case of unsuccessful Dendroctonus beetle attack or the infestation by bark maggots, but the result will not be nearly as serious as when the larva is left in the tissue to complete its life cycle. From the investigation it also developed that one experienced man could practically clean and keep clean an area 50 miles square or, roughly, 1,600,000 acres of this class of damage within a few years. The long period of three years that is required for the insect to develop from egg to adult is a decidedly strong factor in the case of its control. Considering the amount of annually "loggable" Douglas fir from such an area under the mixed-stand conditions that ordinarily obtain, and the percentage of depreciation wrought by the insect, the employment of such caretakers would appear to be a good investment, even if there were no other insect problems requiring the attention of the men.

If in the future lumbering interests are not to pay the same tax to the pitch moth of our time as is now contributed, due to the depreciation of timber a century and more ago, the present day is the time to aid in the elimination of this pitch moth.

As is apparent from the foregoing text relating to the larva and to the seasonal history of the moth, two generations of larvæ, excluding the overlapping percentage at high altitudes and from late oviposition, may be found at any time of the year. For example, by July 1, 1915, the issue from the 1912 oviposition will have emerged and between that date and September 1, when the pitch tubes produced by the issue of the 1915 oviposition are sufficiently developed to be readily seen, only larvæ from the 1913 and 1914 issue are to be found. From September 1 until June 1, 1916, when the 1913 issue

will emerge, 3 generations, those of the issues of 1913, 1914, and 1915, may be located and destroyed at one time. However, no matter how close the examination, a few infested pitch tubes will always escape notice. It is therefore advisable that the same area be scouted several times in the course of each season. After an area is once cleared it should not be a difficult task to keep the insect in check and much the less so if control projects cover big sections.[1]

Destruction of the larva is the only remedy that can be used to reduce an infestation. When the infested pitch tube is located, it should be separated from the tree, the thus exposed larva killed, and to insure cleaner healing the ragged edges of the wound should be smoothed with a knife or small ax, after which they should be painted with creosote or a similar preparation, to prevent reinfestation by insects or fungi. The enlarging of the wound by the smoothing of its edges will also leave a pitch blister in the tissues, but the ultimate result will not be nearly as disastrous as from the untreated sesiid wound, since a clean healing from the inside obviates much of the chance of its producing a circular seam. Freshly vacated wounds might be treated the same way with profit.

SUMMARY AND CONCLUSIONS.

That the financial loss caused by *Sesia novaroensis* in Douglas fir product is great and represents a greater leak in profits to manufacturers than any other avoidable item is evident.

That the depreciation for which this age is taxed can be eliminated for the benefit of posterity at an expense so low that it is but a fraction of that which the damage represents seems to be sufficiently demonstrated by the results of the investigations and experiments.

The manufacturer will always bear the greater extent of the loss, and the manufacturing interests should inaugurate the elimination of the insect by putting into effect a policy of paying better prices for timber where it is clear of pitch seams and reducing the price commensurately for material where logs are defective to an appreciable extent, instead of paying a uniform amount of so much per thousand feet in a locality, without consideration of existing conditions. This would create among owners of forest lands a stimulus to produce clear timber, free of pitch seams, by a little attention annually, and even if the immediate desire should be merely the obliteration of the evidence on young trees by which the defect in the merchantable material is determined, for the purpose of deceiving the lumber cruisers, it would nevertheless produce the desired end.

[1] Under "Habitat" and "Host Trees and Character of Injury" is suggested where to look for infested trees.

On account of the long life cycle of the Douglas fir pitch moth its elimination, in any country where forestry is sufficiently advanced to be a profitable business and where the forests are taken care of as they should be in order that they may be profitable, will follow. In the range of the Douglas fir there are millions of acres of forest land which are inaccessible and practically worthless at the present day, but they will remain so not much longer, and with advanced methods in forestry *Sesia novaroensis* is bound to disappear ultimately. The process of its eradication will necessarily be slow, but this is no reason why a systematic policy to attain this result should not now be adopted in areas which have been and are being logged and which, it is certain, will be logged again when the reproduction attains merchantable size.

While in this paper only the more serious result of pitch-moth infestation during the first 40 years' growth of trees is considered, it does not mean that the insect does no damage in older and mature trees. As is seen under "Host trees," it infests these also under favorable conditions, but in such cases the infestation results only in the so-called "gum spots," the pitch blisters being too near the surface of the trees to cause serious breaks and ultimate "pitch seams" by mechanical strain in the part of the tissues rendered inflexible. In regard to the "gum spots" in Douglas fir, which entail practically no loss to mills, but for which the builder and consumer foots the bill entirely, the pitch moth is responsible for not more than 10 per cent, *Dendroctonus pseudotsugae* for not less than 70 per cent, and all other causes for about 20 per cent of the damage.

SYNONYMY.

Aegeria novaroensis Henry Edwards, Papilio, v. 1, 1881, p. 199; Grote, New Check List N. Amer. Moths, 1882, p. 12; Beutenmüller, Bull. Amer. Mus. Nat. Hist., v. 4, 1892, p. 172.

Sesia novarocnsis Smith, List Pepid. N. Amer., 1891, p. 20; Beutenmüller, Bull. Amer. Mus. Nat. Hist., v. 8, 1896, p. 133; Beutenmüller, Memoirs Amer. Mus. Nat. Hist., Monograph of the Sesiidæ of North America, 1902, p. 289.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 256

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER July 27, 1915.

KATYDIDS INJURIOUS TO ORANGES IN CALIFORNIA.

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Scientific Assistants, Tropical and Subtropical Fruit Insect Investigations.

INTRODUCTION.

There are at the present time in the San Joaquin Valley of California over 43,000 acres of land devoted exclusively to the cultivation of citrus. The citrus strip lies along the Sierra foothills between Bakersfield and Fresno. Although some citrus trees have been grown in this area for more than 25 years, most of this great acreage has been planted in the last 15 years. The transformation of this strip of land from a semiarid grain-growing belt into an irrigated fruit-growing area has so changed the status of certain formerly obscure species of insects native to the locality as now to bring them into prominence as pests.

One of the more important of these species is the fork-tailed katydid, *Scudderia furcata* Brunner. The amount of damage done by this insect has increased considerably since 1910, when it first came to the attention of the senior author. In 1912 it caused a loss in several orchards of a full fourth of the crop.

Associated with the fork-tailed katydid in the orange groves and closely resembling it is the angular-winged katydid, *Microcentrum rhombifolium* (Sauss.). This insect is also responsible for a certain amount of injury to orange trees annually, feeding voraciously, as it does, upon the leaves. It is, however, of much less importance than the former, and is treated here rather because of close association with and resemblance to the fork-tailed katydid than on account of its economic importance. No distinction has heretofore been made between these two species in the orange groves of California.

THE FORK-TAILED KATYDID.

NATURE AND EXTENT OF INJURY.

The fork-tailed katydid (*Scudderia furcata* Brunner), so named from the peculiar forked appendage at the tip of the abdomen in the male,

NOTE.—Technical descriptions of two katydids causing serious damage to oranges in California are contained in this bulletin. Remedies and methods of control are discussed.

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is so large that a day's feeding by a single individual may mean the destruction of several small oranges. Once an orange is attacked it is invariably rendered unfit for sale, and therefore usually left on the ground in the field at picking time.

The young katydids are on the trees and actively feeding at about the time the latter are beginning to lose their petals, and the injury usually begins at this stage. The insect will sometimes attack the blossom buds, generally gnawing a hole through the petals to reach the pistil and ovary, these organs often being destroyed in a considerable number of blossoms (figs. 1, 2). The petals themselves have apparently but little attraction for the insect.

FIG. 1.—Orange bud injured by katydids. (Original.)

Whenever as many as 15 or 20 of the nymphs are found on a tree, the injury to the immature fruits becomes quite noticeable and a quantity badly chewed will be found on the ground (Pl. I, fig. 1). The injured oranges usually have been more than one-third destroyed or have received one or more holes large enough to admit the head and thorax of the slender katydid nymphs, such holes often extending entirely through the oranges. Many other oranges which have been two-thirds or more eaten away will be indicated by the portions remaining on the trees. The oranges which have been only slightly chewed when small and those which receive the injury after they are considerably grown and have "set" firmly to the tree remain to ripen only to be "culled" out either at picking time or in the packing-house. At picking time many of these damaged fruits are conspicuous owing to the clean-cut circular holes in the rind, which vary from the size of a dime to about that of a silver dollar (Pl. I, fig. 2; Pl. II, fig. 1). The insects have the habit, however, of chewing into the larger fruits from the side toward the tree trunk, seeking the shade and also protection from birds, and the injury may not then be noted until the fruit is picked. The holes in the more mature fruits, as in the very young ones, are often deep, extending through the rind and rag, well into the pulp. Many oranges are split wide open as the result of katydid injury inflicted when they were only about one-fourth matured, due to inability to expand along the dried edges to accommodate growth (Pl. II, fig. 2). All oranges which have been attacked after the crop has thoroughly set mature with the sound fruit on the trees, and although edible they must be considered a dead loss, since they are unfit for shipment.

FIG. 2.—Young Navel orange from which the pistil remains and part of the fruit has been eaten by katydids. (Original.)

Examination in the orchards of hundreds of boxes of oranges throughout the San Joaquin Valley during the picking seasons of

1911 and 1912 showed the injury to be very widespread. Very few orchards were examined which failed to indicate the presence of this katydid by the unsightly chewed fruit, either in the boxes or discarded as worthless upon the ground about the trees (Pl. II, fig. 2).

In 1912, before the picking season commenced, an examination was made of all the fruit on 10 or more trees in each of 53 orchards of Washington navel oranges scattered throughout the orange district to determine the total injury to the mature fruit. Only 3 of these orchards were entirely free from katydid-injured fruit. In 3 of the remaining orchards the damage, though present, amounted to less than 1 per cent. In the remaining 47 orchards from 1 per cent to 39 per cent of the maturing crop was rendered totally unfit for sale by the katydids. Fourteen of the 47 orchards suffered a loss of 10 per cent or more of the crop. The total loss of fruit from this cause for the 47 orchards averaged 8.2 per cent of the entire maturing crop. These estimates do not, of course, include the very young fruits which are completely destroyed soon after the petals are off, and this loss is rarely noted at all by orange growers.

The orchards in which the injury is excessive are not necessarily in isolated locations, as has been supposed, nor are they growing under any unusual conditions. The katydid, however, appears to be slightly more abundant in the foothills regions, and it shows some preference for young and vigorously growing orchards.

Several groves which had previously suffered but slightly from katydids were called to the attention of the writers in 1911 and 1912 because of the increasing injury. Thus an orange grower informed the writers that he had seen the familiar circular holes cut in the fruit by katydids on his place for 14 years. Such a small percentage of fruit was affected, however, that he had paid no special attention to it until the fall of 1911, when he noted a material increase in injury. Just after the crop was picked in 1912 a visit was made to his orchard and the injury found much worse than in 1911. The pickers had just finished a 6-acre plat of young navel trees, from which they had discarded 12,000 oranges because of katydid injury. About 100 boxes of oranges were therefore ruined in this 6-acre block of trees, and as 800 boxes of good oranges were picked from these trees a complete loss of 11 per cent of the mature crop plus an undetermined percentage of young fruits and blossoms which might have become fruit was sustained. A 15-acre orchard of young Washington navel trees, which were but slightly infested in 1911, became seriously infested in 1912. When the final picking was made, 533 boxes of good oranges were secured from the orchard, while approximately 175 boxes, 21,000 oranges by count, were rejected as worthless because of splits, gashes, and holes caused by katydids.

The most striking example of injury by this katydid that has come to the attention of the writers was that of a navel-orange grove so

grossly infested in 1911 that 57 per cent of all the mature fruit was ruined. This was determined by actual count made at picking time. Many undeveloped, badly chewed oranges on the trees and the usual dried remains of other riddled fruits on the ground were not taken into account in this examination. These trees, which should have produced, at the very least, 2 boxes of oranges each, averaged only about 7 sound oranges per tree. In 1912 the injury was again very great in this orchard. A large amount of fruit was chewed and destroyed while still small, and the average number of oranges was but 9 per tree after all dropping had ceased and the fruit had matured.

It should be mentioned that, to the present time, the most severely damaged orchards are generally those in which the trees are 10 years of age or younger, although several of the older orchards suffered greater injury in 1912 than in any previous season.

Injury to Valencia oranges.—Examination of all the fruit on several trees in each of 15 Valencia orange groves showed this variety quite as susceptible to attack by katydids as the various navel types, the percentage of injury being practically the same in both.

Injury to foliage (Pl. III, fig. 1).—The fork-tailed katydid, as well as the angular-winged katydid, feeds during its entire life upon the leaves and stems of orange trees. It selects by preference the new, tender growth, filling the leaves with holes and often completely destroying the stems. The injury to foliage has not been serious except on trees where the nymphs were unusually numerous.

FOOD PLANTS.

Under the conditions prevailing in the San Joaquin Valley citrus area, the fork-tailed katydid feeds almost exclusively upon the sweet oranges, where at all times the food supply is abundant and attractive. It has not been taken upon any other variety of citrus. Weeds are rarely allowed to grow in the orchards and, except in early spring, do not flourish on the unirrigated lands surrounding them. The insect has not in a single instance been found upon native weeds.

On one occasion, in October, 1911, the senior author heard a male of *Scudderia furcata* stridulating in a patch of string beans. Examination of the plants disclosed two adult females, and a bean leaf was found which contained two eggs. The following month he found eggs of the species in the leaves of apple and peach trees growing near orange trees. The insect was reported to the writers by an orchardist as injuring grapevines on his place. This report was verified and the injury found upon both leaves and berries.

Other writers have reported the insect as occurring upon "weeds," "coarse grasses," "thickets," "hedges," etc. Its food plants undoubtedly comprise widely different species in various sections of the United States. Under the name *Scudderia curvicauda* (De Geer) it

FIG. 1.—YOUNG NAVEL ORANGES RIDDLED WITH HOLES BY KATYDIDS. (ORIGINAL.)

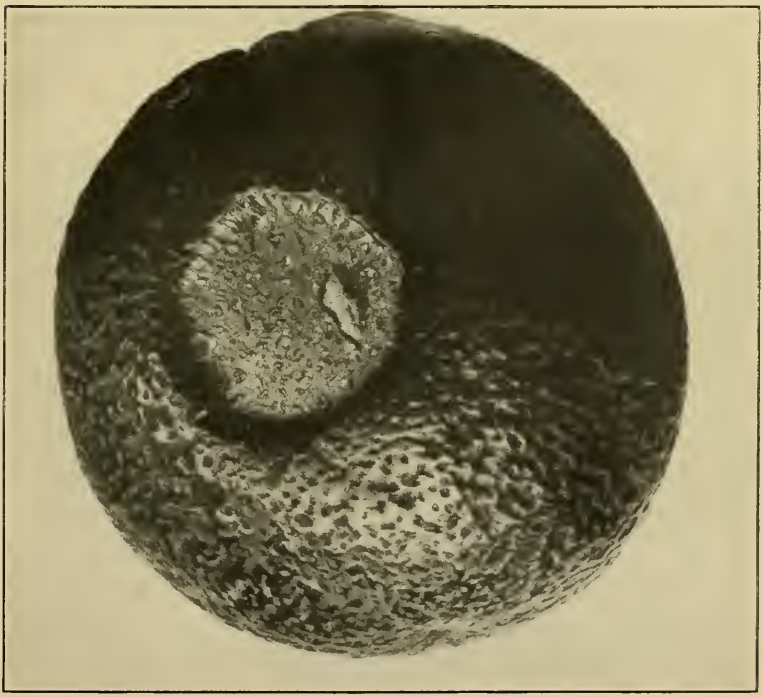

FIG. 2.—RIPE ORANGE SHOWING KATYDID SCAR AND THE BEGINNING OF SPLITTING. (ORIGINAL.)

INJURY TO ORANGES BY KATYDIDS.

FIG. 1.—ORANGE TREE SHOWING OUTSIDE FRUIT INJURED BY KATYDIDS. (ORIGINAL.)

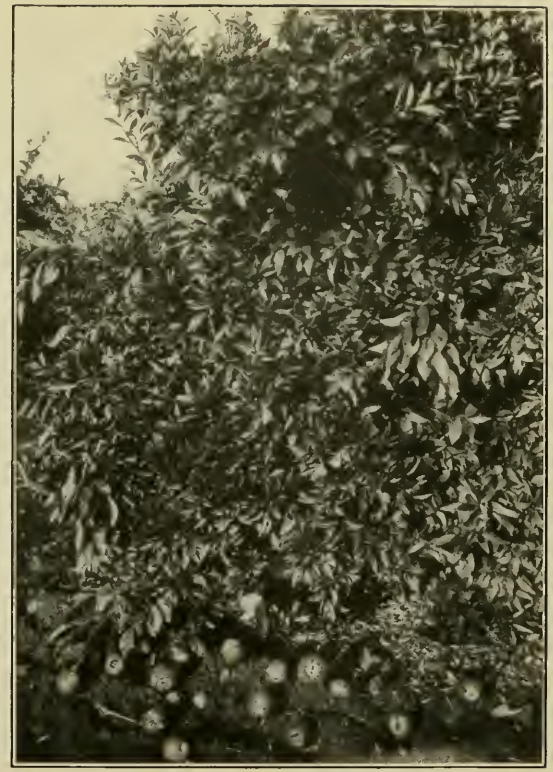

FIG. 2.—ORANGES INJURED BY KATYDIDS AND DISCARDED ABOUT THE TREES AT PICKING TIME. (ORIGINAL.)

INJURY TO ORANGES BY KATYDIDS.

FIG. 1.—ORANGE LEAVES INJURED BY KATYDIDS. (ORIGINAL.)

FIG. 2.—THE FORKED-TAILED KATYDID (SCUDDERIA FURCATA): ADULT FEMALE. ABOUT TWICE NATURAL SIZE. (ORIGINAL.)

THE FORKED-TAILED KATYDID AND DAMAGE TO ORANGE LEAVES.

has been reported by Riley[1] as feeding mostly on oak leaves and showing a preference for depositing its eggs therein.

LIFE HISTORY AND HABITS.

The Egg.

The egg (fig. 3) may be described as follows: Length, 4.5 mm.; breadth, 1.87 mm.; greatest thickness (when first deposited), 0.5 mm. Light gray; smooth, glistening; flat, ovoid, slightly reniform.

The egg is completely hidden from ordinary observation in the plant tissues; in fact, most eggs are inserted into the edges of the older and rather tough leaves, between the upper and lower surfaces. They are at first difficult to detect, but after practice their presence may be recognized by certain outward indications. The edge of the leaf where the egg is inserted is generally slightly chewed away, and with a lens the sharp tip of the egg may often be seen protruding from the cut. When the chewed places are not in evidence, the presence of an egg may be recognized by a slight oval swelling in the edge of the leaf. More rarely from one-fourth to one-half of the egg may be found protruding from the edge of the leaf. Occasionally two eggs are deposited side by side, and in course of growth they may break through the epiderm and remain exposed along an entire side. A suspected leaf, when held to the sun, will show the complete outline of any eggs which may be present. Eggs are occasionally found inserted into the angular edges of tender orange stems. At times the female eats a hole through a leaf and deposits eggs in the edge of the hole. Most eggs will be found in leaves well concealed within the spread of the tree, being thus protected, as well as may be, from enemies and frost. The number deposited in a single leaf ranges from 1 to 10, rarely more than 10; the average greatest number being but 3.

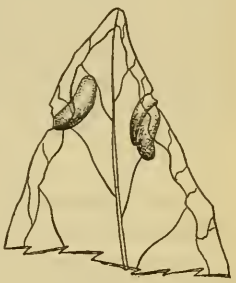

FIG. 3.—Eggs of the fork-tailed katydid (*Scudderia furcata*) in position in an orange leaf. About twice enlarged. (Original.)

During the first warm days of spring the eggs begin to swell through the development of the embryo. Shortly before hatching the egg is almost three times as thick laterally as when first deposited, the swollen areas in the leaf being therefore much more easily detected at this time than in fall or winter. In hatching, the two lateral halves of the eggshell separate along the outer third of their length, and the nymph slowly forces its way out head foremost. Experiments with a large number of eggs showed that hatching may take place even in leaves which have fallen to the ground and become dried out, provided they are kept fairly moist by exposure to the

[1] Riley, C. V. Sixth Annual Report on the Noxious, Beneficial, and other Insects of the State of Missouri, p. 164–166. Jefferson City, Mo., 1874.

winter rains. If, however, the leaves are kept perfectly dry, a large percentage of the nymphs fail to extricate themselves from the egg-shell. This observation suggests the possibility that the species may successfully pass the winter in the egg stage even in deciduous leaves and in its most northerly range, provided these leaves are sufficiently protected from freezing by a covering of dead leaves and snow.

INCUBATION PERIOD.

Eggs have never been observed to hatch during the year they were deposited, and in the San Joaquin Valley they invariably pass the winter in the leaves on the citrus tree. The average duration of the egg stage, as determined in 1911 and 1912 from 68 eggs deposited between July 14 and August 6, was 286 days. Eggs deposited in July averaged about 290 days; those deposited in August, about 275 days. Those deposited later in the year undoubtedly have a shorter duration, since the period of hatching for all is short. In general, the incubation period lasts from the maximum period of deposition, about the middle of August, to the maximum period of emergence, which, in 1912, was about the middle of May, or 275 days.

ENEMIES OF THE EGG.

A small chalcidid parasite, determined by Mr. J. C. Crawford as belonging to the genus Anastatus, is the most important, and indeed the only enemy of the egg discovered during the investigation. This parasite, though perhaps the most important natural check to the species, is much more effective in checking the angular-winged katydid, to which it largely confines its attacks. On March 22, 1912, a quantity of orange leaves, each containing one or more eggs of *S. furcata*, was gathered and kept in condition for the hatching of the eggs. On April 2 adult parasites began to emerge from these eggs and continued to do so for one and one-half months, or until May 18. The proportion of eggs parasitized in the lot under observation was 25 per cent. The eggs were taken at random from all parts of an orchard, and it seems reasonable to assume that fully 25 per cent of all the eggs in this orchard were parasitized.

General appearance of adult parasites.—The little parasites running over the orange leaves resemble small, winged black ants. They are very active, glossy black, reflecting metallic bronze-green in the sunlight. They have two pairs of membranous wings, the fore pair in the female being almost covered by a large, brownish spot; both pairs are transparent in the male. The female is about one-eighth inch long, the male considerably smaller. Only one parasite issued from a single katydid egg in any case observed. The insect escapes from the side of the parasitized egg. The oviposition of Anastatus has not been observed.

The Young.

GENERAL APPEARANCE.

The young katydids of this species vary in length from one-sixth to three-fourths inch, depending on their age. Immediately after issuing from the egg they are of a pale flesh color, without visible vestige of wings. The head and mouth parts are large in proportion to the rest of the body; the antennæ are long and slender and usually directed forward. The larger nymphs, with rudimentary wings or "wing-pads," are bright green, closely matching the color of the orange leaves on which they rest. They resemble somewhat the young of the short-horned grasshoppers (Acridiidæ), except for the long, slender antennæ. They usually remain motionless upon the leaves or move over to the side away from the observer when too closely approached. Ordinarily at the approach of danger they become perfectly motionless in every part and, simulating the leaf color closely, are readily overlooked. When sufficiently disturbed, however, they show ample power as leapers, and will jump a foot or more.

FIG. 4.—The fork-tailed katydid (*Scudderia furcata*): First-instar nymph. About three times natural size. (Original.)

FIG. 5.—The fork-tailed katydid: Basal segments of the antenna of first-instar nymph. Greatly enlarged. (Original.)

DESCRIPTION OF INSTARS.

The young katydid grows slowly for an average period of about 73 days, during which time it molts six times before final emergence as a mature insect.

First instar (fig. 4).—Measurements: Greatest breadth of head, 1.10 mm.; greatest breadth of abdomen, 0.75 mm.; length of body, 4.10 mm.; length of pronotum, 0.70 mm.; length of posterior femur, 4.20 mm.; length of antenna, 10 mm. Just after issuance from the egg the nymph is of a pale flesh color. The legs, head, and thorax are irregularly marked with small blotches of red, purple, and white; the abdomen, with about ten longitudinal rows of minute red and white spots, the most conspicuous of which are one row of dark spots on either side of the middorsal yellow line and two rows of white spots below these on either side of the abdomen. The newly issued nymph is about one-sixth inch long. The fastigium, which is most prominent in this stage, is about one-half as long as the club-like basal segment of the antenna (fig. 5). Antenna with five distinct, broad white rings at regular intervals from tip to base, and with two narrow, less distinct white rings near the base; spaces between the rings dark purple. Head broad, thorax comparatively narrow, abdomen considerably enlarged toward tip. The lateral edges of sclerites

forming the dorsum of the mesothorax and metathorax appear as little flap-like, evenly rounded processes folded down over the upper portion of the episterna and epimera of their respective segments. These semicircular processes are the wing rudiments and are distinctly characteristic of this instar.

Second instar (fig. 6).—Measurements: Breadth of head, 1.3 mm.; greatest breadth of abdomen, 1.4 mm.; length of body, 6 mm.; length of pronotum, 1.1 mm.; length of posterior femur, 6.1 mm.; length of antenna, 14 mm. The markings on the body are the same as in the preceding instar, but the ground color of the abdomen is bright green, making the spots on it less conspicuous. The small, flaplike wing rudiments are now almost equilaterally triangular, with nearly pointed and but very slightly rounded tips. The bright green color of the abdomen and the triangular shape of the wing-pads readily distinguish this stage from the preceding one. Just after the first molt the nymph is about one-fourth inch long.

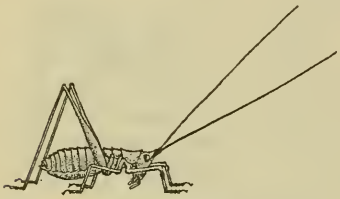

FIG. 6.—The fork-tailed katydid: Second-instar nymph. Somewhat more than twice enlarged. (Original.)

Third instar (fig. 7).—Measurements: Length of body, 7.4 mm.; length of pronotum, 1.55 mm.; length of posterior femur, 7.5 mm.; length of antenna, 17 mm. The general color and markings of the body are as in the second instar, the intensity of the green coloring varying in different individuals. In this and succeeding instars the head and abdomen are less broad compared with the thorax than in instars I and II. The wing rudiments are triangular as in the second instar, but their hind margins extend downward and very slightly forward, while the front margin extends more abruptly backward than in preceding stages, thus making the sides unequal in length. Faint evidences of wing-veins may be distinguished at this stage. Just after molting to this instar the nymph is about one-third inch long.

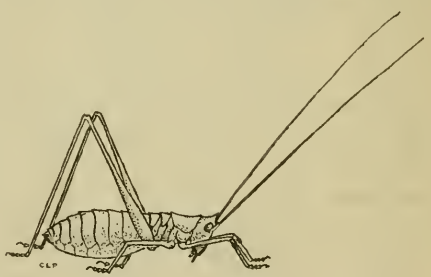

FIG. 7.—The fork-tailed katydid: Third-instar nymph. Three times natural size. (Original.)

Fourth instar (fig. 8).—Measurements: Length of body, 10 mm.; pronotum, 2.3 mm.; posterior femur, 10.8 mm.; antenna, 24 mm. Color as in preceding instar. Wing-pads appressed to sides of mesothorax and metathorax as in preceding instars, but both front and hind margins extending downward and backward; posterior pair reaching well over on the sides of the first abdominal segment. About eight veins can be readily distinguished in the hind wings and a few

are faintly visible in the forewings. The pronotum covers about one-half the dorsum of the mesothorax. The sexes can be distinguished in this stage by the appearance of the external genitalia. Just after the third molt the nymph is about two-fifths inch long.

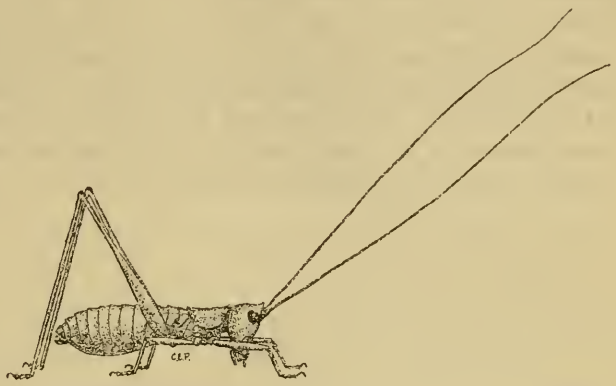

FIG. 8.—The fork-tailed katydid: Fourth-instar nymph. About three times natural size. (Original.)

Fifth instar (fig. 9).—Measurements: Length of body, 12.5 mm.; pronotum, 3.1 mm.; posterior femur, 13 mm.; antenna, 26 mm. In this instar the position occupied by the wing-pads is different from that in any of the earlier instars. They now lie partly over the abdomen in a tectiform position, this change being brought about by the previously outwardly exposed sides being brought out, upward, and in leaving the inner sides exposed roof-shape above the body. The tips of the posterior wing-pads now reach to the hind margin of the second abdominal segment; wing-pads similar in shape, in position relative to the body, and in venation to the adult wings. Pronotum completely covering the dorsum of the mesothorax. The young of this instar are about one-half inch long shortly after the molt.

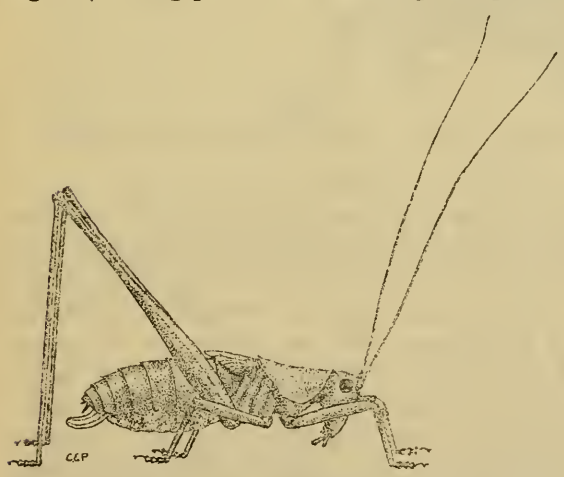

FIG. 9.—The fork-tailed katydid: Fifth-instar nymph. About three times natural size. (Original.)

Sixth instar (fig. 10).—Measurements: Length of body, 16 mm.; pronotum, 4.5 mm.; posterior femur, 18.5 mm.; antenna, 3.9 mm. In this instar the nymphs resemble adults in almost every particular except the smaller size of the wings. Just after molting the wings extend rooflike over the abdomen to the ninth segment, the dorsal

edges meeting near their tips. With feeding and growth of the nymph the abdomen elongates without a corresponding growth of the wings, with the result that the latter reach only about to the sixth abdominal segment just before transformation to the adult. The prothorax extends slightly over the dorsum of the metathorax. The white rings on the antennæ, which have grown gradually fainter with each succeeding molt, are now but faintly visible. The external genitalia, the ovipositor in the female and the forked, supraanal spine in the male, appear to be almost as fully developed as in the adult. The nymph is about five-eighths inch long just after the molt to this instar.

FIG. 10.—The fork-tailed katydid: Sixth-instar nymph. About three times natural size. (Original.)

DURATION OF INSTARS.

The duration of instars, averaged from all our records, was as follows: Instar I ranged from 10 to 35 days, with an average of 18.8 days; instar II ranged from 8 to 13 days, with an average of 9.7 days; instar III ranged from 4 to 12 days, with an average of 7.1 days; instar IV ranged from 6 to 10 days, with an average of 8.3 days; instar V ranged from 3 to 15 days, with an average of 10.4 days; instar VI ranged from 12 to 20 days, with an average of 14 days. The complete nymphal stage required from 58 to 88 days. Nymphs issuing early in the spring were slower to become adults than those issuing later when the average temperatures were higher.

MOLTING.

After feeding for from 1 to 3 weeks the nymph ceases to eat and remains sluggish for from 24 to 48 hours. The skin then splits along

the middorsal line from between the eyes to a point between the posterior wing-pads. The insect hangs helplessly, head downward, suspended by the posterior claws, and gradually works its way out of the dead skin. The head, thorax, fore-legs, intermediate legs, wings, abdomen, and hind legs are freed from the exuvium in the order named. During the entire process the antennæ are held lightly between the maxillary palpi and pulled and guided carefully from their position along the ventral surface of the body.

ENEMIES OF THE NYMPH.

A common gray jumping spider, determined by Mr. Nathan Banks, of the Bureau of Entomology, as *Thiodina puerperis* Htz., has been observed to capture the small nymphs of the first instar. This active, solitary spider is quite numerous on orange trees in the San Joaquin Valley, and feeds upon insects of several orders, injurious and beneficial alike. The very young spiders capture insects as minute as the citrus thrips.

In 1911 a small chipping sparrow was noted in some abundance among trees of various katydid-infested orchards, and was apparently very busily capturing katydids. Birds are undoubtedly the most important enemies of the katydid in this section.

The Adult.

GENERAL APPEARANCE.

The adults (Pl. III, fig. 2) are dark green, their color blending almost perfectly with that of the orange leaves. They habitually seek the shady interior of the tree during the heat of the day, thus adding to the difficulty of discovery, even when fairly abundant. Their length is about 1½ inches from vertex to tip of wings. When they are at rest, the wings, which are narrow and rounded at the tips, are closely folded along the sides of the body. In flight the stiff, outstretched wings and the habit of sailing for considerable distances with scarcely any wing movement give them a fancied resemblance to a monoplane.

EMERGENCE AND MATING.

As a rule most of the nymphs transform to the adult stage early in the summer, though the exact time of beginning emergence varies more or less in different years. In 1912 adults were fairly numerous by June 15 and practically all of the insects were in the adult stage by July 5. In 1911 the period of emergence was slightly later than in 1912, and nymphs were found in the field until about July 17.

Mating usually takes place about 20 days after emergence, the time elapsing between the last molt and the first copulation varying from 14 to 40 days. Females which have recently mated can usually,

if not always, be detected by the extrusion near the base of the ovipositor of a bilobed translucent, jellylike mass of unknown character, which is visible for several hours.[1]

Specimens in captivity have mated as often as six times in a period of about 120 days. Union of the sexes perhaps occurs less often in the field. The stridulation note of the male is a short, soft rasp, usually given one, two, or three times in succession. The note is produced by rubbing the short, filelike process, extending diagonally across the under surface of the forewings, over the thin margin of the hind wings. At times it appears to be a sexual call, at other times merely a note of alarm; it is most persistent at night.

OVIPOSITION.

Oviposition, which has been observed by the writers many times, has already been described in some detail by Riley.[2] Variations from Riley's account were noted in the orange groves near Lindsay, Cal., as follows: For a period of about 10 seconds the female generally cleanses, or possibly lubricates, the convex edge and tip of the ovipositor with her mouth before the deposition of each egg. The ovipositor is always held firmly between the mandibles from the moment its tip touches the edge of the leaf until the blade is finally withdrawn from the latter. As the ovipositor is forced between the leaf surfaces the two pairs of blades comprising it move slowly back and forth, alternately, over each other with a distinct though slight rotatory motion. The apical third of two of the blades is finely notched, sawlike, along the concave margin, the other pair being similarly notched along the convex margin. At the beginning of oviposition the ovipositor is worked into the leaf for almost its entire length, thus forming a pocket to contain the egg. Without pause the organ is then withdrawn to half its length, and the abdomen begins to expand and contract rhythmically, forcing the egg between the blades of the ovipositor into the cavity in the leaf. The complete operation of depositing one egg requires about four and one-half minutes.

Rate of oviposition and number of eggs deposited by single females.—A female of *Scudderia furcata* has been seen to deposit as many as 9 eggs in 45 minutes. This high rate of oviposition is not, however, long maintained, and after depositing such a number the female usually ceases to oviposit for from one to four days. Eggs are seldom deposited for more than three days in succession. During the summer

[1] Similar protrusions have been noted following mating in the females of other Locustidæ. The writers have observed it on the female of *Microcentrum rhombifolium* Sauss.; C. P. Gillette has seen and described it on *Anabrus simplex* Haldeman; R. E. Snodgrass has noted the phenomenon in connection with the mating of *Pcranabrus scabricollis* Thomas; and it had previously been observed in *Scudderia furcata* Brunn. by A. N. Caudell.

[2] Loc. cit. Due to a misidentification the name here used is *Scudderia curvicauda*.

the usual number of eggs, from 1 to 3, are laid overnight, at which time oviposition mostly occurs. Oviposition decreases during the fall months and usually ceases entirely about midwinter. Females which have ceased to oviposit in winter may be induced to begin again by placing them in an artificially warmed atmosphere. Thus, one of a number of females which had ceased to oviposit about the middle of November, when taken from a temperature of 40° F., early in December, and placed in a room heated to 75° F., began to oviposit and laid 8 eggs in the course of an hour. A single female in the course of her life deposits, on an average, about 175 eggs. Infrequently individuals held in captivity from the middle of July to the following December have deposited about 230 eggs. The following complete individual records were obtained from specimens which emerged in captivity and were kept there, under nearly field conditions, until death:

TABLE I.—*Oviposition record of the fork-tailed katydid, Lindsay, Cal., 1912.*

No. of specimen.	Number of eggs deposited.	No. of specimen.	Number of eggs deposited.
1	169	10	206
2	172	11	74
3	121	12	140
4	174	13	230
5	114	14	87
6	64	15	142
7	78	16	239
8	132	17	61
9	57	18	159

Most of the eggs of this species are deposited during the period from the latter part of July to the last of September, though oviposition still occurs as late as the first week in December in warm winters, and adults have been found ovipositing as early as June 18.

LENGTH OF LIFE OF ADULTS.

Adults reared in screened cages, protected from their natural enemies and given an abundance of fresh food daily, lived, on an average, 125 days, or a little over four months. In a few exceptional cases individuals lived from 150 to 160 days—162 days in the case of a single specimen being the record longevity.

ENEMIES OF THE ADULT.

Birds undoubtedly play an important part in reducing the number of adults each year. Under field conditions adults are less numerous in October and November than in July and August, yet specimens protected by large screen cages live through October and most of November as actively as during the first few weeks of their adult life. In certain orchards where the infestation was particu-

larly bad in 1911 and 1912 large numbers of adult katydids disappeared in August and September. At about the same time large numbers of small birds of an undetermined species were noted in and about these orchards. These little birds were unquestionably responsible for the disappearance of katydids.

Seasonal History.

As there is but one generation of the fork-tailed katydid annually, the duration of the life cycle is approximately one year. The average life cycle, as determined from a number of complete rearings in 1911 and 1912, was 367 days, ranging from 343 to 383 days. The first nymphs to appear issued about April 20, the majority issuing during May. Nymphs are most abundant in May and June, but have occasionally been seen as late as August 15. The first adults appear early in June, are fairly numerous by the last of June, and most abundant during July and August. They can be found without much difficulty in September and more rarely in October. The last specimens of the season were captured December 3. A few have been kept alive in screen cages until early January.

THE ANGULAR-WINGED KATYDID.

NATURE AND EXTENT OF INJURY.

The angular-winged katydid (*Microcentrum rhombifolium* Sauss.) somewhat closely resembles the fork-tailed katydid and is closely associated with the latter on orange trees in the San Joaquin Valley. It is, however, larger than the fork-tailed katydid and may be readily distinguished from that insect by its size, broader wings, and in the nymph by its hunchbacked appearance. Although responsible for a certain amount of injury to orange trees annually, it attacks only the foliage and rarely does enough damage to cause alarm. This insect has been present in Florida orange groves for years without, except in rare cases, causing sufficient damage to attract attention. This is also the case in California. The observations of the writers indicate that the minor position of the angular-winged katydid as a pest is largely due, first, to the high percentage of parasitism suffered by the eggs; and, second, to the fact that the insect does not attack the fruit. That it might injure the fruit if able to increase to the point of crowding is quite possible. The insect is also exposed to the attacks of various enemies, chiefly birds, because of its large size and slowness of movement. The first-instar nymphs feed principally if not wholly upon the leaf surface, removing merely a chlorophyll layer. Later stages gnaw clear through the leaves, filling them with ragged holes, and destroy a larger amount of foliage in proportion to their number than does the fork-tailed katydid. The insect has never been seen to attack blossoms or fruit.

FOOD PLANTS.

In the San Joaquin Valley orange section the angular-winged katydid, like the forked-tailed katydid, confines itself all but exclusively to orange trees. Its eggs have been found a few times upon an undetermined native weed, the latter always growing near orange trees. Adults have been found upon grapevines adjoining an orange grove, and males have repeatedly been heard loudly stridulating in large pepper trees (*Schinus molle*) about Lindsay, Cal. According to Riley[1] an allied species, *Microcentrum retinerve* (Burm.), feeds upon a great variety of foliage, including oak, apple, and cherry.

DISTRIBUTION.

The angular-winged katydid has apparently about as wide a range as *Scudderia furcata*, having been reported from the New England States, Florida, and California. It occurs throughout the central California citrus belt with the fork-tailed katydid, though it is not so often found because less numerous.

LIFE HISTORY.

The Egg.

The egg (Pl. IV, fig. 1) may be described as follows: Length, 5.18 mm.; breadth, 2.47 mm.; thickness when first deposited, 0.5 mm.; thickness just before hatching, 2.2 mm. Color light grayish brown; elongate ovoid, flat to almost cylindrical laterally, depending upon the degree of development.

The eggs are glued in double rows along the sides of twigs from one-eighth to one-fourth inch in diameter. These selected twigs may be inside the leaf shelter of the tree or on the exterior. There may be from 3 to 28 or more eggs in a batch, each egg overlapping the one above it. The two rows always occur if more than one egg is deposited, each egg of one row alternating with an egg in the other row. The larger egg groups of this insect, composed of 24 or more eggs, each about one-fifth inch long, are decidedly conspicuous.

INCUBATION PERIOD.

The average duration of the egg stage is about 225 days. Eggs deposited the last of September hatch in about 228 days, while those deposited about the middle of October hatch in approximately 212 days. The time required for incubation thus depends upon the time of season deposited, the period of hatching being shorter than the period of deposition. Eggs laid from September 20 to September 30 hatched from May 10 to 15, while those deposited between October 20 and 30 hatched from May 15 to 20.

[1] Op. cit., p. 155–161.

HATCHING.

When the egg is ready to hatch, the lateral halves split at their juncture along its edge for about one-third the length from the upper end, the nymph slowly forcing itself through the opening thus made.

ENEMIES OF THE EGG.

The greatest natural check to the increase of the angular-winged katydid in California is the egg parasite, *Anastatus* sp., already referred to in connection with *Scudderia furcata*. Anastatus parasitizes a large percentage of all eggs deposited by this insect each year. It is quite usual to find large batches of katydid eggs, each egg showing the small, circular exit hole of the parasite (Pl. IV, fig. 1). It is, in fact, rare to find eggs of this katydid entirely free from evidence of parasitism. Anastatus oviposits in the katydid eggs in September and October, the larva feeding upon the egg contents during the remainder of the fall and the adult emerging the following spring. All reared specimens have emerged between March 19 and May 18. It seems probable that 80 per cent or more of all eggs deposited by *M. rhombifolium* are destroyed by this little insect. For example, a lot of eggs collected in widely separated locations in the fall of 1911 produced 43 adult Anastatus, representing 86 per cent parasitism. Of another lot of 109 eggs 35 per cent produced living parasites and the remainder failed to hatch.

THE NYMPH.

DESCRIPTION OF INSTARS.

The nymph of the angular-winged katydid may be easily distinguished from that of the fork-tailed katydid by its plump body and highly arched back, which gives it a decidedly humpbacked appearance. The nymphs vary in length from one-sixth to three-fourths inch, depending upon the stage of development. Their color is grass-green throughout, including the long, threadlike antennæ. There are six periods of development, or instars, which may be described as follows:

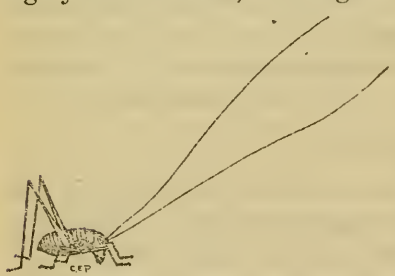

FIG. 11.—The angular-winged katydid (*Microcentrum rhombifolium*): First-instar nymph. Slightly over twice natural size. (Original.)

First instar (fig. 11).—Measurements: Length of body, 4 mm.; length of head (vertex to tip of jaws), 2 mm.; length of pronotum, 0.72 mm.; length of posterior femur, 4.75 mm.; length of posterior tibia, 5 mm.; length of antenna, 16 mm.; subovate, convex along dorsum and nearly flat along ventral surface. Color grass-green,

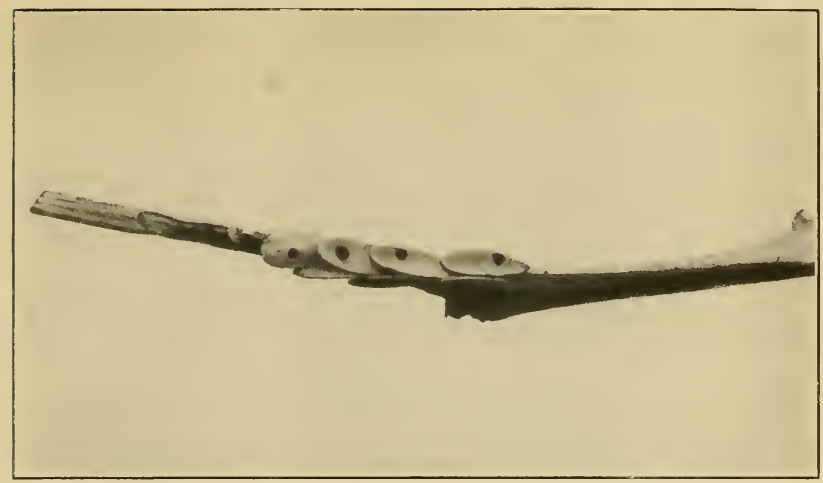

FIG. 1.—EGGS OF THE ANGULAR-WINGED KATYDID (MICROCENTRUM RHOMBIFOLIUM), SHOWING EXIT HOLES OF THE PARASITE, ANASTATUS SP. TWICE NATURAL SIZE. (ORIGINAL.)

FIG. 2.—THE ANGULAR-WINGED KATYDID: ADULT MALE. THREE-FOURTHS ENLARGED. (ORIGINAL.)

THE ANGULAR-WINGED KATYDID.

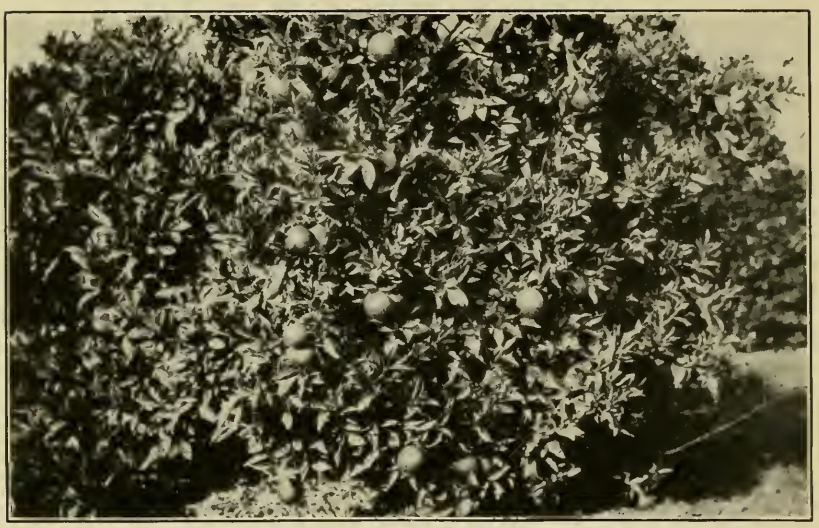

FIG. 1.—A ROW OF SPRAYED ORANGE TREES BEFORE PICKING. [THE TREE IN FOREGROUND REPRESENTATIVE OF ALL SPRAYED TREES.] (ORIGINAL.)

FIG. 2.—VIEW IN AN EXPERIMENTAL ORCHARD IN CALIFORNIA. (ORIGINAL.)

with minute black dots in longitudinal rows, forming one crossrow upon each abdominal segment near hind margin; legs marked with more conspicuous black dots.

Second instar (fig. 12).—Measurements: Length of body, 6 mm.; length of head, 2.4 mm.; length of pronotum, 1.14 mm.; length of posterior femur, 5.8 mm.; length of posterior tibia, 6 mm.; length of antenna, 21.96 mm. Shape and color of body about as in first instar.

Third instar (fig. 13).—Measurements: Length of body, 7.5 mm.;

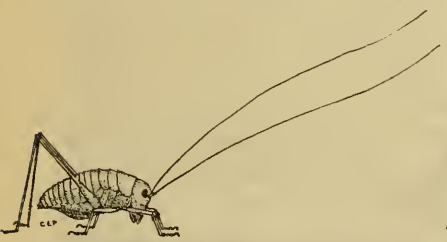

FIG. 12.—The angular-winged katydid: Second-instar nymph. Somewhat over twice natural size. (Original.)

FIG. 13.—The angular-winged katydid: Third-instar nymph. Nearly three times natural size. (Original.)

length of head, 2.9 mm.; length of pronotum, 1.6 mm.; length of posterior femur, 8 mm.; length of posterior tibia, 8 mm.; length of antenna, 20.25 mm. Color and shape of body as before, except that black spots are less conspicuous.

Fourth instar (fig. 14).—Measurements: Length of body, 10 mm.; length of head, 3.75 mm.; length of pronotum, 2.66 mm.; posterior femur, 10 mm.; posterior tibia, 11 mm.; antenna, 20 mm. General color of body light green, merging into yellow on sides of abdominal segments; abdomen white beneath, or nearly so. Wing-pads sufficiently developed to be distinctly recognizable as such, hind pair showing well-developed veins and just overlapping first abdominal segment; tips of wing-pads directed downward and slightly backward.

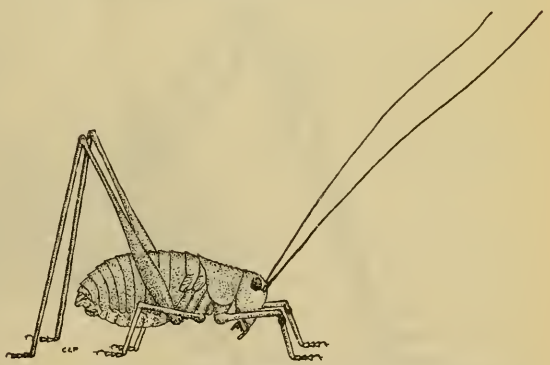

FIG. 14.—The angular-winged katydid: Fourth-instar nymph. Two and one-half times natural size. (Original.)

Fifth instar (fig. 15).—Measurements: Length of body, 15 mm.; length of head, 4.5 mm.; length of pronotum, 4 mm.; posterior femur, 13.25 mm.; posterior tibia, 14.5 mm.; antenna, 29 mm.

Color about as in preceding instar; body more strongly arched. Wing-pads more distinctly veined, their tips directed backward over the abdomen, reaching to middle of second segment.

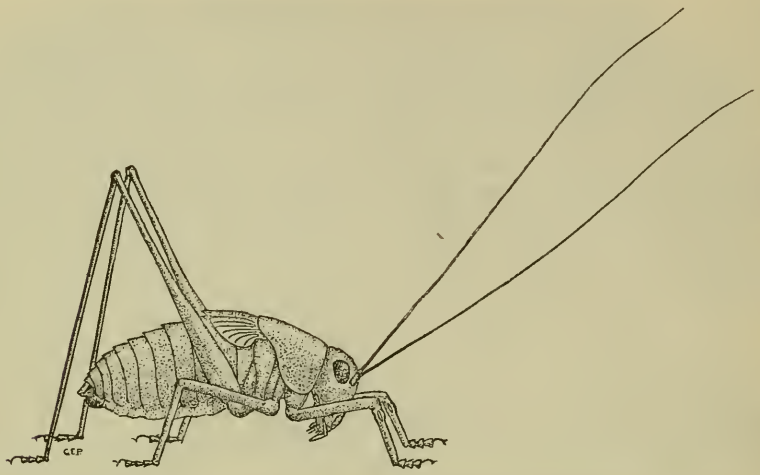

FIG. 15.—The angular-winged katydid: Fifth-instar nymph. Two and one-half times natural size. (Original.)

Sixth instar (fig. 16).—Measurements: Length of body, 17 mm.; length of head, 5.7 mm.; length of pronotum, 5 mm.; posterior femur, 16.5 mm.; posterior tibia, 17.7 mm.; antenna, 37.4 mm. Body strongly arched above, sloping about equally abruptly in both

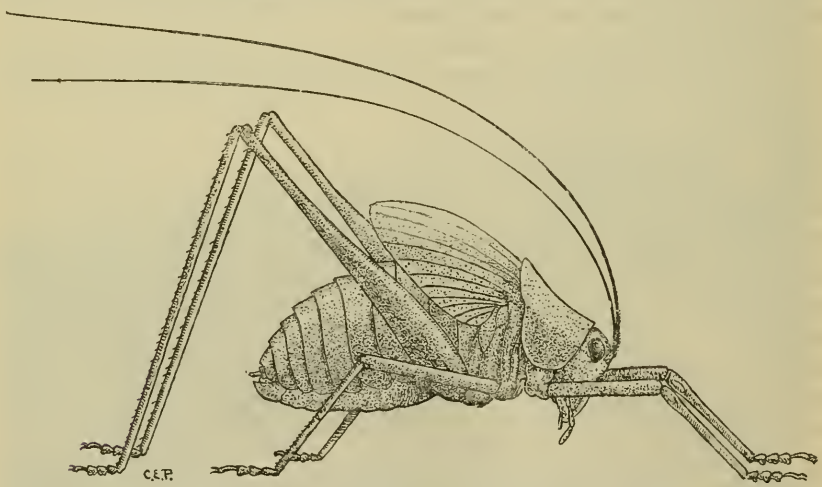

FIG. 16.—The angular-winged katydid: Sixth-instar nymph. Almost three times natural size. (Original.)

directions from second abdominal segment; wings projecting upward and backward at an angle from abdomen; tips considerably elevated above latter.

Nymphal instars each described from a single specimen shortly after molting.

DURATION OF INSTARS.

The average duration of the nymphal instars of the angular-winged katydid, as determined from a number of individual rearings, was as follows: Instar I, 13.8 days; instar II, 8.6 days; instar III, 9.5 days; instar IV, 10.2 days; instar V, 13.7 days; instar VI, 17.2 days. The average duration of the complete nymphal stage is therefore 73 days, or about 2½ months. Molting is accomplished in about the same manner as by the fork-tailed katydid (see pp. 10–11. The nymph always eats the greater part of its cast skin after each molt, rejecting only the mandibles, claws, and certain hard parts of the head cast.

The Adult.

GENERAL APPEARANCE.

The body of the adult is broad and compact, and comparatively very wide dorsoventrally (Pl. IV, fig. 2). The humpbacked appearance so characteristic of the later stages of the nymph is retained, but to a lesser degree, owing to the broadly rounded angle of the forewings. The hind wings extend the full length of the body beyond the tip of the abdomen. The color is uniform grass-green over most of the body, becoming yellowish green on the ventral surface. The insect is fully 2 inches long, the wings measuring, when spread as for flight, about 3½ inches.

MATING.

Mating rarely or never occurs earlier than 18 days after emergence, and the period between emergence and the first union of the sexes ranges from 18 to 26 days. Coitus is succeeded by the extrusion of a small, bilobed mass of albuminous material, which, as in *Scudderia furcata*, may be seen clinging to the abdomen at the base of the ovipositor in the female for several hours subsequent thereto. The favorite time for mating is at night, when the males are very active and may often be heard sending forth a loud and sustained clatter for several hours at a time. The stridulating note, once heard, is readily recognized, and to trace it to its source will often disclose both male and female katydids, as stridulation appears to be closely connected with courtship. The stridulating song of an allied species, *Microcentrum retinerve* Burm., has been described by Riley as consisting of "a series of from 25 to 30 raspings, as of a stiff quill drawn across a file" at the rate of "about five of these raspings or trills per second, all alike, and with equal intervals, * * * the whole strongly recalling the slow turning of a child's rattle." This description is equally applicable to *M. rhombifolium*.

OVIPOSITION AND LENGTH OF ADULT LIFE.

In captivity females have deposited from 3 to 123 eggs each during

the course of life, and in the orchard under normal conditions they probably deposit more than the maximum number here given, since on one occasion 133 eggs, showing advanced development, were removed from the ovisac of a female which had not oviposited during her entire life in captivity. The number of eggs laid at one time varied from 3 to 28. The adults live from three to three and one-half months, and are present in the orchard almost continuously from the middle of August to the middle of November. Adults lived in screen cages from 85 to 111 days.

Seasonal History.

Most of the eggs of this species are deposited during September and October, and all eggs secured from females in captivity in 1911 and 1912 were deposited between September 4 and October 29. The eggs hatching the following spring, the nymphs make their appearance about the first of May. They reach the maximum abundance between May 15 and July 15 and will seldom be seen after the middle of August. Adults are most numerous during the period from August 15 to October 15; they are scarce in November and rare in December, finally disappearing entirely in January.

CONTROL OF KATYDIDS ON ORANGES.

Several methods have been suggested for the control of katydids on oranges, among which the following have been found to be impractical: Destroying the nymphs by hand; gathering by hand and destroying the eggs; poisoning by the use of trap crops or by poisoned baits. It would be extremely difficult, if not impossible, to find any large percentage of eggs or nymphs, and the method would certainly prove too slow and tedious. The katydids can not be attracted from the fruit and foliage of the orange by any crop or bait while such an abundance of food so much to their liking is always at hand. Unless practically forced to quit the orange tree, they spend their entire lives upon the tree on which they are born.

SPRAYING EXPERIMENTS.

Spraying with arsenicals is generally considered to be impractical for the control of grasshoppers and locusts because of the large dose necessary to kill these robust insects and the difficulty of applying such a dose evenly and with safety to the trees. These objections would doubtless hold with the citrus katydids if the spraying were done after the insects had reached an advanced nymphal or the adult stage. They do not hold, however, when the trees are properly sprayed while the insects are still largely in the first, second, or third nymphal instars.

Preliminary Tests with Arsenicals.

Four groups of 10 Washington navel trees each were sprayed on April 15, 1912, for the purpose of determining the maximum strength of the different arsenicals that could be used with safety to the trees and to compare the adhesive qualities of the insecticides. The spraying was done in bright, warm weather and the trees were thoroughly drenched. The test trees were examined on April 19, and although covered with tender, new leaves not the slightest trace of burning resulted. Subsequent examinations in no case revealed burning or damage resulting from the spray application. It was later found safe to use considerably stronger solutions of the arsenicals, the maximum strengths of which were (1) arsenite of zinc, 2 pounds (powdered) per 100 gallons of water, and (2) arsenate of lead, 8 pounds (dry) per 100 gallons of water. The distribution of the arsenicals over the leaf surface after the spray dried did not seem entirely satisfactory, especially on the young leaves, whose waxy surface had caused the water to gather in drops, leaving the poison in spots. The addition of lime-sulphur solution to the arsenical sprays and the regulation of the nozzles so as to deliver a moderately fine spray remedied this objection.

Plan of Experiments.

The principal spraying experiments conducted against the katydids are outlined in Table II. Each of the sprayed plats consisted of two rows of 33 trees each, or 66 trees to the plat. Three pairs of rows of trees extending through the midst of the sprayed area and the trees adjoining the sprayed area on the west were left unsprayed as checks. (See experimental orchard, Pl. V, fig. 2.)

Table II.—*Plan of spraying experiments against citrus katydids, Lindsay, Cal., 1912.*

No. of plat.	Insecticides in gallons and pounds per 100 gallons of water.		
	Lime-sulphur solution.	Arsenite of zinc.	Arsenate of lead.
	Gallons.	*Pounds.*	*Pounds.*
1	2	2	.....
2	2	3	.....
3	2	4	.....
4	2	.....	4
5	2	.....	6
6	2	.....	8
7	.....	2	.....
8	.....	3	.....
9	.....	.....	4

Plats 1, 2, 4, and 5 received two applications containing lime-sulphur and arsenicals and one application of lime-sulphur alone; plats 3 and 6 received one application containing both lime-sulphur and arsenicals and two applications of lime-sulphur alone; plats 7, 8, and 9 received only two applications of arsenicals alone. The chief purpose of adding lime-sulphur to the sprays was to make them effective against the citrus thrips. The third application was directed solely against this insect, only two applications of arsenicals being made in any case. The applications were timed, also, partly with a view to controlling thrips as well as katydids, and the dates of beginning were May 22, June 3, and June 24, respectively.

Results.

The efficiency of the sprays in killing katydids was determined by a comparison of the number of living insects occurring in the sprayed and unsprayed blocks some days after spraying was completed. Arsenite of zinc at the rate of 2 pounds per 100 gallons killed 93.1 per cent of the fork-tailed katydids and 100 per cent of the angular-winged katydids. Arsenate of lead at the rate of 4 pounds per 100 gallons killed 100 per cent of the insects in each case.

The results of the season's spraying work were principally manifested in three ways: (1) By preventing a complete loss of a certain amount of fruit by dropping; (2) by almost complete prevention of katydid injury to the mature fruit and the leaves and reduction in the amount and severity of thrips injury; and (3) by improvement in the amount and vigor of growth of the sprayed over the unsprayed trees.

PREVENTION OF DROPPING.

During July, fruits injured by both katydids and thrips were very conspicuous on the unsprayed trees, at once attracting the attention when one entered the orchard. While in the orchard on August 9 the senior writer noted that badly injured outside fruit was decidedly less in evidence on unsprayed trees than had been previously the case. The cause of this disappearance of fruit was soon found; it had fallen to the ground. By counting all the fruit on and under 10 unsprayed trees it was found that 18.7 per cent of the crop had fallen from these trees. Examination of the fruit which had fallen, for the location of the insect injury, disclosed 62.8 per cent of it full of holes, while 83.3 per cent were severely marked by thrips. Many of these fruits had been eaten into near the point of attachment to the stems. However, much of the dropped fruit during this period was caused by thrips injury, the most severe dropping due to katydids coming earlier in the season when very small fruits were chewed to pieces by these insects. At all events, the 18.7 per cent of dropped

fruit at this time was principally due to katydids and thrips. No fruits had fallen at this time from sprayed trees, as examination of the ground under 15 trees disclosed.

At picking time it became evident that a much larger saving of fruit than that just indicated resulted from spraying. During October and November all the fruit of all sprayed plats and checks was counted, from which it was found that from 60 to 100 per cent more fruit was produced in each of the sprayed plats than in their unsprayed checks. (See Pl. V, fig. 1.) The trees of the different plats varied greatly in size and condition, however, and it was therefore necessary to know how many trees in each plat produced the fruit of that plat. By eliminating the stunted, rebudded, and dead trees, resets, and blank spaces in each plat it was found that the full-bearing, unsprayed trees matured only 54.2 per cent, or just a little over half as many oranges per tree as the full-bearing trees of the sprayed plats. The saving of crop in all sprayed plats taken together due solely to spraying was, therefore, practically 100 per cent. A greater saving was effected in plats sprayed with lime-sulphur and arsenicals mixed than in those sprayed with arsenicals alone, the former producing a little over twice as much and the latter only one and one-half times as much fruit per tree as the checks.

PREVENTION OF INJURY TO MATURED FRUIT.

The results of the spraying experiments in preventing katydid injury to the final crop of fruit were determined by examination, in the field at picking time, of all oranges in all plats. For convenience of reference these results are shown in Table III.

TABLE III.—*Results of spraying experiments with lime-sulphur and arsenicals in preventing injury to oranges by katydids, Lindsay, Cal., 1912.*

Insecticides and dilution.	Sprayed fruit.		Unsprayed fruit.	
	Percentage of sound fruit.	Percentage of culled fruit.	Percentage of sound fruit.	Percentage of culled fruit.
Plat 1: Arsenite of zinc, 2 pounds; lime-sulphur, 2 gallons, per 100 gallons water	100.00			
Plat 2: Arsenite of zinc, 3 pounds; lime-sulphur, 2 gallons, per 100 gallons water	99.99	0.01	80.5	19.4
Plat 3: Arsenite of zinc, 4 pounds; lime-sulphur, 2 gallons, per 100 gallons water	99.85	.14		
Plat 4: Arsenate of lead, 4 pounds; lime-sulphur, 2 gallons, per 100 gallons water	99.85	.14	80.9	19.0
Plat 5: Arsenate of lead, 6 pounds; lime-sulphur, 2 gallons, per 100 gallons water	99.86	.13		
Plat 6: Arsenate of lead, 8 pounds; lime-sulphur, 2 gallons, per 100 gallons water	99.77	.22	82.3	17.6
Plat 7: Arsenite of zinc, 2 pounds, per 100 gallons water	99.92	.07		
Plat 8: Arsenite of zinc, 3 pounds, per 100 gallons water	99.92	.07		
Plat 9: Arsenate of lead, 4 pounds, per 100 gallons water	99.84	.15		
Average	99.88	.11	81.45	18.55

As shown in Table III, two applications of arsenite of zinc, at the rate of 2 pounds per 100 gallons plain water (plat 7) or dilute lime-sulphur solution (plat 1), gave practically the same results as one application at the rate of 4 pounds per 100 gallons (plat 3), being sufficient in each case to kill the katydids and insure approximately 100 per cent sound fruit. Two applications of arsenate of lead, at the rate of 4 pounds per 100 gallons plain water (plat 9) or dilute lime-sulphur solution (plat 4), were practically as effective as the arsenite of zinc and gave just as good results as when used at the rate of 8 pounds per 100 gallons with but one application (plat 6).

The addition of lime-sulphur to the arsenicals, besides being absolutely essential where it is desired to control both katydids and the citrus thrips, increased the adhesive quality of the arsenicals and facilitated their even distribution over the leaves and fruit. This was especially noted after a slight rain, occurring May 25, when the combination sprays appeared to be very little affected. Lime-sulphur solution itself without the addition of arsenicals proved deterrent to the katydids and measurably reduced the amount of injury to the fruit. It also, therefore, appears to have some insecticidal value against these insects.

RECOMMENDATIONS.

On the basis of the foregoing results the writers make the following recommendations for the control of katydids on oranges in the San Joaquin Valley:

1. Two applications of arsenite of zinc at the rate of 2 pounds per 100 gallons of water; or,

2. Two applications of arsenate of lead at the rate of 4 pounds per 100 gallons of water.

The first application should be made, at the latest, immediately after most of the petals have fallen; the second application, from 10 days to 2 weeks after the first. If it seems desirable to spray for the citrus thrips also, lime-sulphur should be added to the above at the rate of 2 gallons per hundred, and a third application of lime-sulphur only, at the same dilution, should be made about two or three weeks after the second.

The cost of spraying will vary somewhat according to size of trees, cost of labor, team hire, insecticides, etc., but with ordinarily good management will not exceed $5 per acre.

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(PROFESSIONAL PAPER.)

AMERICAN PLUM BORER.[1]

By E. B. Blakeslee, *Entomological Assistant, Deciduous Fruit Insect Investigations.*

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INTRODUCTION.

In the summer of 1912, while engaged in deciduous fruit insect investigations at Winchester, Va., the writer's attention was attracted by the common occurrence upon apple of the American plum borer, *Euzophera semifuneralis* Walk. Although injury to fruit trees by the larvæ of this insect was recorded by Forbes in Illinois as early as 1890, very little has since been published concerning it. This lack of attention may be attributed to the fact that though common and widely distributed it has never occurred in sufficient numbers or been sufficiently destructive to call upon it any special notice as an economic species.

The food habits of this insect are particularly interesting when contrasted with those of other wood-boring species. It is also an insect that under certain conditions is capable of doing considerable damage to trees which have been injured either mechanically or by the attacks of fungous diseases. At the suggestion and under the direction of Mr. A. L. Quaintance, of the Bureau of Entomology, an attempt was made, therefore, in the summer of 1913 and 1914, to study the insect's biology.

For the photographs presented in this paper the writer is indebted to Mr. Fred E. Brooks, of the Bureau of Entomology.

[1] *Euzophera semifuneralis* Walk.; order Lepidoptera, family Pyralidæ.

HISTORY.

This species was first described by Walker, in 1863, under the name of *Nephopteryx semifuneralis*. In 1881 Zeller redescribed and figured it as *Euzophera impletella*. In 1887 Hulst described the species as *Stenoptycha pallulella*. In 1889 we find the first published reference to the immature stages of this insect; S. A. Forbes, in his report for that year, described the larvæ as injuring Chinese plum (*Prunus simoni*) in Illinois. Forbes gave it the common name of American plum borer. In 1891 D. S. Kellicott reported it as injuring mountain ash in Ohio, and in 1898 Otto Lugger included it in a list of "Butterflies and Moths Injurious to our Fruit Producing Plants." In 1901 E. D. Sanderson reported it as injuring apple and Kieffer pear in Delaware, giving a few notes on its probable life history in that locality and renaming it the "fruit-tree bark borer." Slingerland and Crosby have given a short account of this borer in their recent "Manual of Fruit Insects."

While Forbes's report is the first published reference to the feeding habits of the larvæ of this insect, we find in the unpublished notes of the Bureau of Entomology, February 2, 1879, the following note: "Received from E. A. Schwarz, Jackson, Miss., one cocoon found under bark on fence around cotton field. The moth issued and proves to be either *M. distinctella*, or one that comes very near to it." This specimen was later determined by H. G. Dyar to be *Euzophera semifuneralis* Walk. Again, May 14, 1879, in the notes of the Bureau of Entomology, Theo. Pergande records finding a cocoon on peach and rearing a moth belonging to the Pyralidæ, which he names rather doubtfully *Acrobasis* sp. A later determination by Dyar proved this also to be *Euzophera semifuneralis*.

DISTRIBUTION.

Dyar gives the distribution of this borer as "United States." Zeller described the species in 1881 from four specimens from Colombia, South America, one of which was taken at Mariquita on August 10 and the other at Honda the last of April. Hulst notes that his description was based on specimens from New York, Utah, and Washington. In the United States, specimens in the collection of the United States National Museum, and the correspondence, notes, and collection of the Bureau of Entomology, as well as the literature available, indicate that the insect occurs in the following States: Arkansas, Arizona, Colorado, Delaware, Florida, Georgia, Illinois, Indiana, Kansas, Missouri, Maryland, Mississippi, North Carolina, New York, Ohio, South Carolina, Texas, Utah, Virginia, West Virginia, Washington, and the District of Columbia.

FOOD PLANTS.

This insect does not, by any means, confine its attacks to plum. It has been taken feeding upon plum, peach, cherry, Chinese plum (*Prunus simoni*), Kieffer pear, mountain ash, persimmon, apple, and Russian mulberry. The writer has found it equally abundant on plum, cherry, peach, and apple. It will probably attack the trees of any of the common stone or pome fruits when the proper conditions are presented.

FEEDING HABITS AND CHARACTER OF INJURY.

As has already been stated, the food habits of this insect are of especial interest when contrasted with those of other wood-boring species. The plum borer prefers trees which are not dead and yet are not in a too vigorous condition. The attention of the writer was first attracted to the work of this borer by an apple tree upon which it had established itself. This tree had been partially girdled by a disease commonly known as collar blight. Under the skirt of bark bordering the wounded area the borer had begun its work and by extending its galleries out into the living tissue had completed the girdling of the tree. This seems to be the characteristic form of injury for the species. Beginning at some scar, wound, or crevice, where a bark scale offers partial protection, the larva works its way back into the living tissue, in broad, shallow, irregular galleries just beneath the bark. Apple trees partially girdled by collar blight and trees injured mechanically by frost or by some other factor offer the ideal condition for the work of this borer. Without injury of some sort to its host plant the borer rarely succeeds in establishing itself, and entirely healthy and uninjured trees are in little danger from its attacks. On the other hand, where a tree has suffered injury the work of this borer may, in many cases, considerably shorten its life. Pl. I, *a*, *b*, *c*, shows the character of the galleries and the condition of trees most liable to attack.

DESCRIPTION OF STAGES.

THE EGG.

When first deposited the egg appears as a regular oval, opaque white body, coarsely punctate. The size is fairly uniform, the average for 10 being 0.59 mm. by 0.42 mm. A marked change takes place in the appearance of the egg as incubation proceeds. Twenty-four hours after deposition the color changes from white to a pinkish tint, or in cases where incubation is somewhat delayed to a light brown, and in 48 hours to a dull red. In three to four days a slight depression appears in the center and 24 hours before hatching the color

changes to a dirty white with the head of the larva plainly visible at one end. The unfertilized egg remains white. After hatching the shell is white and retains its shape. The eggs are deposited singly or in small irregular groups, usually in cracks or crevices of the bark, or in the absence of such places they are rather insecurely glued to smooth surfaces (Pl. II, *e*). They are easily broken away from the surface to which they are attached.

THE LARVA.

In leaving the egg the larva (Pl. II, *b*) gnaws out an irregular hole in one end and leaves the shell in two or three minutes. The newly-hatched larva is very active; its color is white throughout with the exception of the very large dark brown head, and the alimentary tract which shows plainly from its reddish coloration. After a few days of feeding the color of the body changes to a dingy white and later to a brownish green, somewhat lighter on the ventral surface. The full-grown larva averages about 25 mm. in length by 3 mm. in width. The head is dark brown; the cervical shield, pale yellow, with black markings on either side. The anal plate is brown and the thoracic legs are light brown with darker tips. There is great variation in the color and size of individual specimens.

THE PUPA.

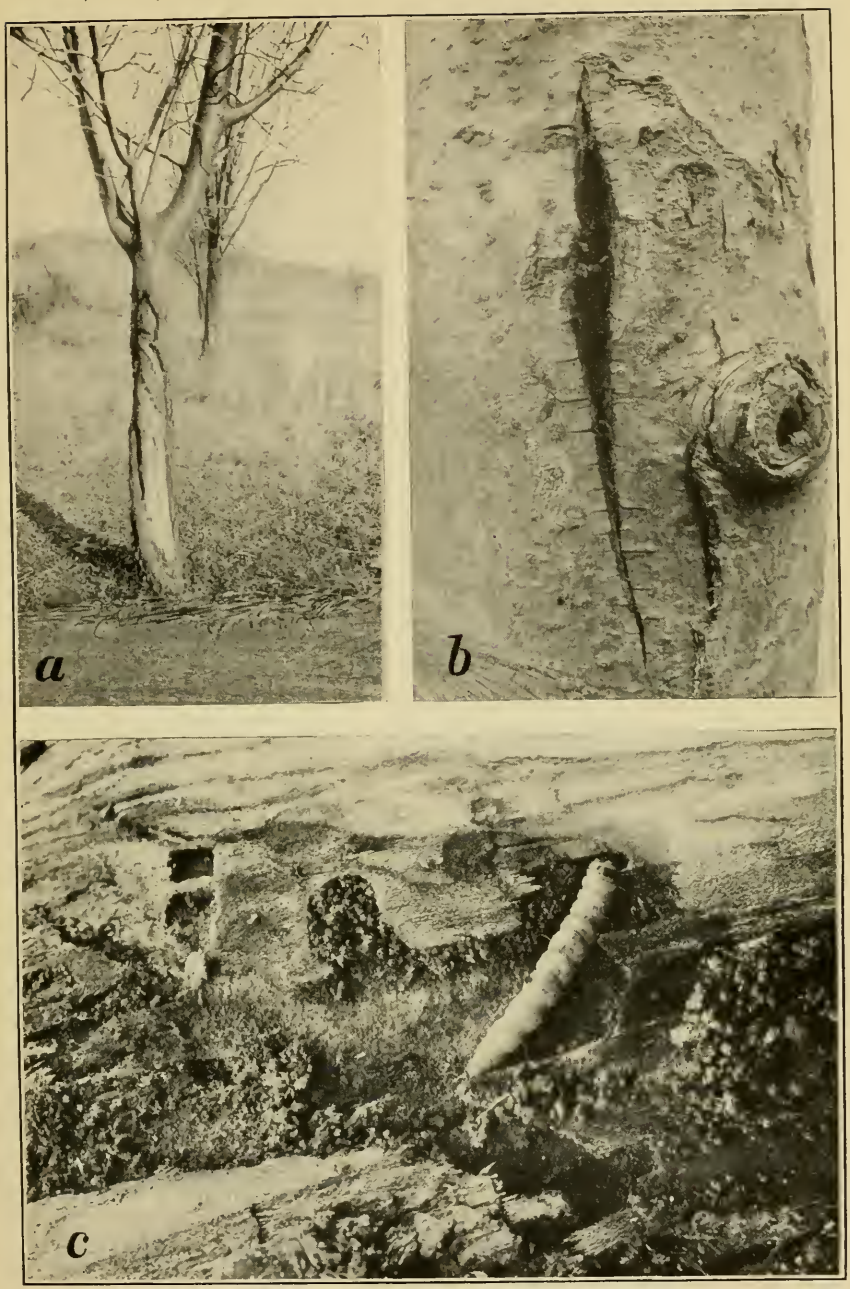
When first formed, the color of the pupa (Pl. II, *f*) is light olive green, which changes in one or two days to light brown and 24 hours before emergence to dark brown and then black. The size is variable, but averages about 10 mm. by 3 mm. The wing sheaths are somewhat lighter brown and extend about two-thirds of the total length of the body. The eyes are black, the spiracles well defined, and the last abdominal segment has a variable number of stout hooked spines.

THE ADULT.

The adult female (Pl. II, *a*) measures about 1 inch across the expanded wings. The average measurements of 10 specimens were: Spread of wings, 19.5 mm.; length of body, 8.4 mm.; width of body, 1.4 mm. The head, thorax, legs, and abdomen are a light gray. The fore wings are grayish brown with a broad, wavy band of black and brown markings across the outer third. There is considerable variation in the color pattern of the fore wings, however, and frequently these markings are almost or entirely absent. The hind wings are smoky with a distinct black marginal line.

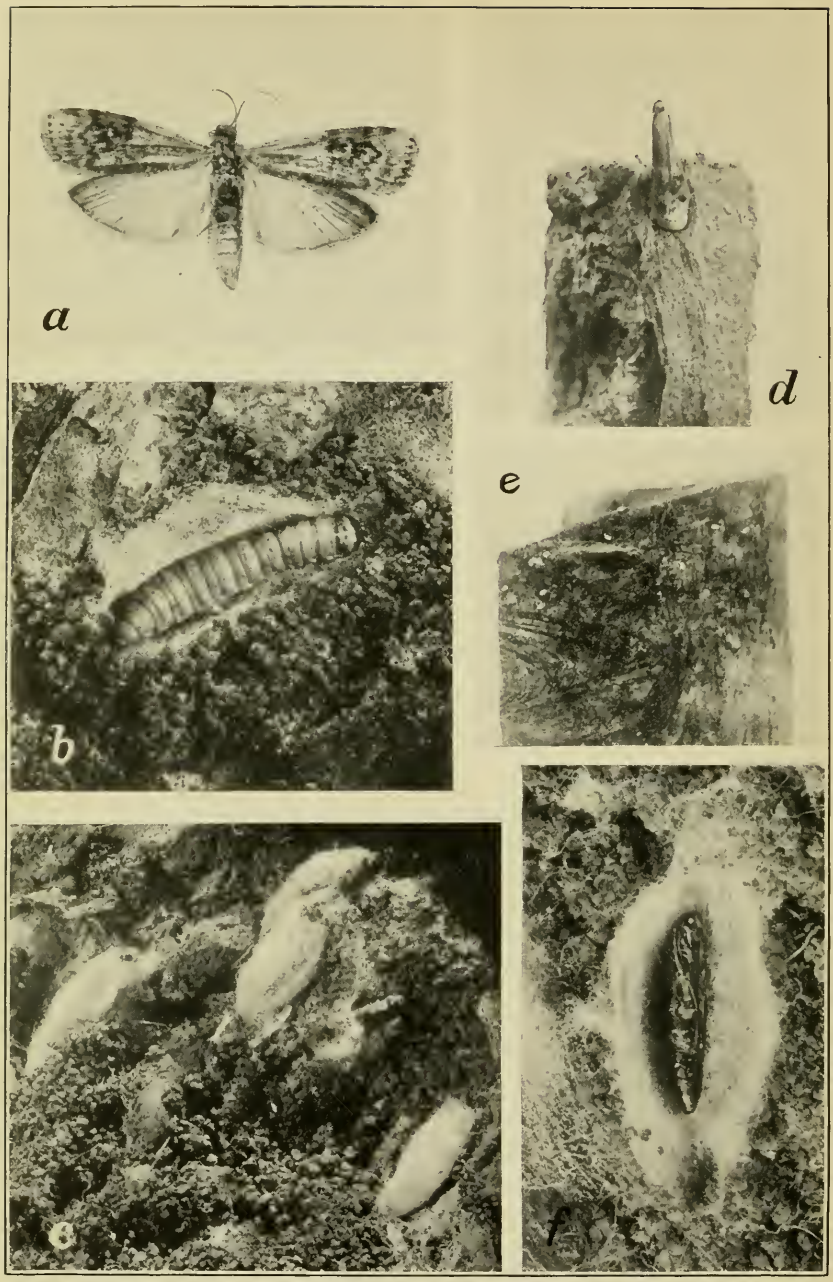
The insect was first described by Walker in 1863. The following is his description:

Nephopteryx semifuneralis n. s. *Female*, blackish cinereous, dingy cinereous beneath. Palpi smooth, slender, hardly curved, obliquely ascending, not rising higher than the



WORK OF THE AMERICAN PLUM BORER (EUZOPHERA SEMIFUNERALIS).

a, Plum orchard in which the trunks of the trees are being injured by the plum borer; *b*, crack in bark of apple tree through which larvæ of the plum borer entered; *c*, galleries and young larva of the plum borer. (Original.)



THE AMERICAN PLUM BORER.

a, Adult, about twice natural size; *b*, winter cocoon opened to show larva, enlarged about one-half; *c*, mass of winter cocoons embedded in frass and silk under scale of cherry bark; *d*, characteristic resting posture of adult; *e*, eggs, about natural size; *f*, cocoon opened to expose pupa, about twice natural size. (Original.)

vertex; third joint lanceolate, nearly as long as the second. Abdomen extending beyond the hind wings; hind borders of the segments pale cinereous; wings moderately broad; fringe long, cinereous. Fore wings hardly acute; middle and exterior lines cinereous, undulating, blackish-bordered; discal mark cinereous, curved; marginal points black; exterior border convex, hardly oblique. Hind wings dark cinereous, very slightly hyaline; marginal line brown. Length of the body 5 lines; of the wings 12 lines.

a. North America. From Mr. Carter's collection.

SPRING PUPATION OF WINTERING LARVÆ.

At Winchester, Va., in the spring of 1913, pupation of the wintering larvæ began about the last of March to the first of April. Frequent collections of larvæ were made previous to and including March 24, and pupation had evidently not begun up to that time. Absence from Winchester prevented further observation for a period of 14 days following March 24, and during this interval, of the 31 larvæ that had been taken in the field previous to that date, 18 had pupated by April 7. However, the temperatures from April 4 to April 7 were so extremely low that insect life generally was almost dormant and most of this pupation must have occurred before the former date.

Girault in 1906 records the pupation of three larvæ under his observation in the insectary at Washington, D. C., as occurring on March 27, 28, and 31, respectively. At Myrtle, Ga., in the same year, both Rosenfeld and Girault observed pupation as early as March 2, or about 25 days earlier than in the latitude of Washington. Girault, in 1905, took four pupæ in the field at Myrtle, Ga., March 1. In the latitude of northern Virginia and the District of Columbia, in a normal season, pupation evidently begins about April 1 or possibly a little before, depending upon the relative lateness of the season, and as far south as Georgia probably a month earlier.

The 23 individual records of the pupal stage included in Table I were taken from field-collected material kept in an out-of-doors rearing shelter. In most cases the larvæ under observation were kept in their winter cocoons (Pl. II, *c*), which are so loosely woven that the transformation of the insect within can be easily seen. Occasionally it was necessary to force the larvæ to spin up in glass vials, but this was avoided as far as possible, as the insect under such conditions probably does not feel the full effect of the changes in outside temperature.

TABLE I.—*Length of pupal period of wintering larvæ of the plum borer, Winchester, Va., 1913.*

No. of observation.	Date of—		Length of pupal period.
	Pupation.	Emergence.	
			Days.
1	Apr. 14	May 17	33
2	14	15	31
3	17	15	28
4	19	16	27
5	19	21	32
6	22	21	29
7	24	18	24
8	24	21	27
9	24	21	27
10	24	21	27
11	25	24	29
12	25	27	32
13	25	27	32
14	26	27	31
15	26	27	31
16	May 2	27	25
17	2	27	25
18	4	June 2	29
19	4	May 30	26
20	5	June 2	28
21	6	2	27
22	6	2	27
23	7	3	27
Maximum			33
Minimum			24
Average			28.43

The longest pupal period observed was 33 days, the shortest 24, and the average of the 23 observations 28.43 days. The records at Winchester show a slightly longer duration of this stage of the insect's life than has been observed by others, though data from other sources are rather limited. Girault, in 1905, notes that one larva pupated in the insectary at Washington March 28 and emerged April 21, a period of 24 days, while Rosenfeld, at Myrtle, Ga., in 1906, reports one insect that transformed from larva to adult in 20 days. Fred Johnson, at Youngstown, N. Y., in 1905, has the following note: "Larvæ confined in jar form cocoons June 28. Adults emerged from these July 20 and others continued to appear until August 4." Evidently some of the insects in this instance transformed in less than 23 days. The weather conditions of the spring of 1913 may be partially the cause of the longer pupal period at Winchester, the unusually high temperature prevailing through March hastening the insect's pupation, while the relatively cold April that followed probably delayed the emergence of moths.

EMERGENCE OF SPRING BROOD OF MOTHS.

Table II gives in detail the time of appearance of 79 moths that emerged at Winchester in the spring of 1913 from field-collected rearing material. The first adult appeared in the laboratory on April 25 and by the fore part of May the insect was emerging in numbers.

TABLE II.—*Emergence of spring brood of moths of the plum borer at Winchester, Va., in 1913. (See fig. 1.)*

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
Apr. 25	1	May 19	3
29	6	23	5
May 3	10	27	1
7	34	31	2
11	6	June 4	8
15	3	8	6
		Total..	79

Girault, in 1905, records one adult that emerged at Washington as early as April 21 and later notes that empty pupal cases were very plentiful in the field by May 2. In normal seasons adults probably begin appearing in the latitude of Winchester and Washington from the last of April to the first of May. Rosenfeld, in 1906, observed emergence in Georgia as early as March 29, or about one month earlier than it occurred at Washington the preceding year. In 1913 maximum emergence occurred at Winchester on May 7, twelve days after the first moth appeared, and adults continued to emerge in the rearing cages in lessening numbers until June 4. The seasonal appearance of the moths can be more easily appreciated by reference to figure 1.

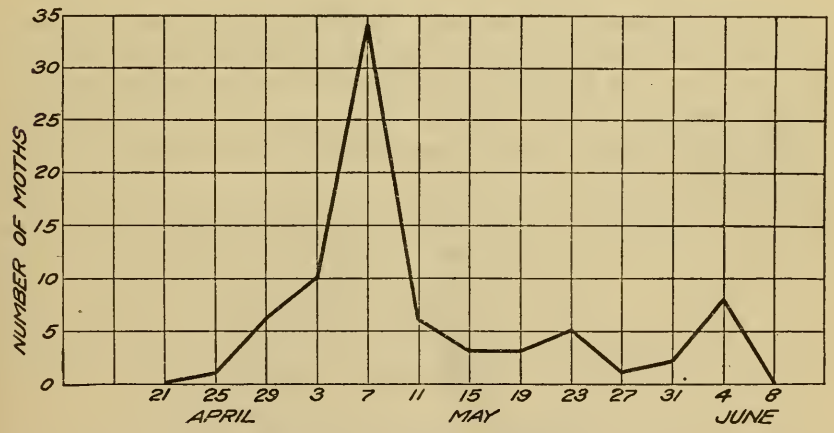


FIG. 1.—Diagram showing emergence of spring brood of moths of the American plum borer (*Euzophera semifuneralis*) at Winchester, Va., in 1913. (Original.)

OVIPOSITION OF FIRST GENERATION OF MOTHS.

As the moths emerged from day to day they were transferred to jars containing twigs of plum or apple wood, all of those issuing on the same date being confined in one jar and a record kept of the number of eggs subsequently deposited. Eggs were laid freely on the twigs, singly or in small groups in the cracks and crevices of the

bark, or very often were rather insecurely glued to the sides and bottom of the jar as well.

From Table III it will be seen that the moths began to oviposit in from 1 to 3 days after emergence, the average for seven observations being 1.7 days. On the average, oviposition lasted 2.3 days, the longest period observed being 4 days and the shortest 1 day. Girault records three moths that oviposited in confinement in the insectary at Washington, May 8, 1905, the duration of oviposition being 2 days.

TABLE III.—*Oviposition of the spring brood of moths of the plum borer, Winchester, Va., 1913.*

No. of cage.	Number of moths.	Date of—			Days—		
		Emergence.	First oviposition.	Last oviposition.	Before oviposition.	Of oviposition.	From emergence to last oviposition.
1	6	Apr. 26	Apr. 29	May 2	3	4	7
2	5	May 2	May 3	6	1	4	5
3	3	3	6	6	3	1	4
4	8	4	5	6	1	2	3
5	5	5	7	7	2	1	3
6	2	5	6	7	1	2	3
7	6	6	7	8	1	2	3
Maximum					3	4	7
Minimum					1	1	3
Average					1.7	2.3	4

Copulation was never observed, but evidently occurred very soon, since in several instances fertile eggs were deposited within 24 hours of emergence. In the absence of the male the female deposits infertile eggs freely.

The number of eggs deposited in confinement per female is indicated in Table IV.

TABLE IV.—*Number of eggs of the plum borer deposited per female in confinement, Winchester, Va., 1913.*

Date.	No. of females under observation.	Number of eggs.	
		Deposited.	Deposited per female.
April 26	1	45	45
May 2	2	50	25
3	2	24	12
5	1	74	74
Average			32.2
Maximum			74
Minimum			12

Records were kept of the number of eggs laid, in two jars containing 2 females each and in two jars containing 1 female each. The

condition of the moths in confinement is of course quite unnatural. The greatest number of eggs laid by one female was 74. In one instance only 24 eggs were deposited in a cage containing 2 females and the minimum is stated as 12, although it is of course possible that only one female was ovipositing.

Girault, May 8, 1905, gives a record of three adults, emerging in the insectary at Washington, that deposited 78 eggs, an average of 26 eggs each. No observations were made in the field that would throw any light on this part of the insect's life cycle.

LENGTH OF LIFE OF MOTHS OF SPRING BROOD.

The length of life of 17 adults is given in Table V.

TABLE V.—*Length of life of moths of the spring brood of the plum borer, Winchester, Va., 1913.*

No. of moths.	Length of life.	No. of moths.	Length of life.
	Days.		*Days.*
1	3	2	11
1	4	1	12
2	6	2	13
1	7	2	15
1	8	1	18
1	9	1	23
1	10	.....	.....
Total		17	139
	Maximum.....		23
	Minimum.....		3
	Average.....		8.2

These moths were supplied with sweetened water. Several cages of moths were given nothing in the way of food or water and several were given water alone. The observations were too limited to justify the drawing of any conclusions as to the influence on longevity of sugar and water compared with water alone, but those given neither, as a rule, lived only a few days after oviposition.

The moths fed upon sweetened water lived from 3 to 23 days, the average of 17 observations being 8.2 days. No data were obtained upon the relative longevity of the sexes.

HABITS OF THE MOTHS.

When resting the moth assumes the characteristic position seen in Plate II, figure *d*, the wings tightly folded, the legs pulled in closely and set far back under the abdomen. The rigid posture of the body and the blending of the ashy grays and dark browns of the fore-wings produce to the human eye at least a close resemblance to a short twig. During the day the moths remain in this posture for hours at a time, and until the eye has become accustomed to this

adaptation of the insect they are easily overlooked in the rearing cages.

As a rule the moths are rather inactive during the day, though egg laying is by no means entirely limited to the hours of darkness. The moths are evidently active at night. Forbes (1890) records taking them at night in Illinois.

INCUBATION OF FIRST-BROOD EGGS.

Table VI shows the incubation period of first-brood eggs.

TABLE VI.—*Incubation period of first-brood eggs of the plum borer, Winchester, Va., 1913.*

Number of eggs observed.	Date—		Period of incubation.
	Deposited.	Hatching.	
			Days.
36	Apr. 29	May 7	8
3	May 2	10	8
8	3	11	8
11	4	12	8
32	6	19	13
38	7	21	14
19	8	21	13
Average			10.3

The shortest incubation period observed was 8 days, the longest 14, and the average for seven lots of eggs was 10.3 days. The long incubation required by the three lots of eggs deposited on May 6, 7, and 8, respectively, is entirely due to the cold wave of May 8, 1913. The temperatures were so extremely low that incubation very probably ceased altogether. The 8-day period required by the first four lots of eggs probably represents more nearly the average incubation period under seasonable temperature conditions. As a rule the incubation period for the individual eggs of a given lot varied only a few hours, and in recording observations for any lot of eggs incubation was considered over when the first egg hatched.

FIRST-BROOD LARVÆ.

An attempt was made to rear larvæ at Winchester on plum wood. A number of old plum trees were transplanted in May to the vicinity of the laboratory. As the larvæ hatched they were transferred to these trees. All began feeding at once. Unfortunately predaceous enemies and parasites destroyed all but one of these larvæ before they reached maturity. This larva hatched on May 7, from the first lot of eggs obtained in the laboratory, spun up on June 10, pupated June 12, and emerged June 22. The feeding period in this case was 34 days; the prepupal period, 2 days; the pupal period, 10 days.

Two pupæ taken in the field on July 14, which from their light olive-green color had just transformed, emerged on July 22, indi-

cating a pupal period in this case of 8 days. Another mature larva taken in the field pupated in the laboratory on July 18 and emerged July 30, giving a pupal period of 12 days. Two moths emerging in the laboratory on July 22 deposited eggs the following day.

A second generation, or, at least, a partial one, occurs in the latitude of Winchester. As just stated, one adult emerged on June 22, from a larva which hatched in the laboratory on May 7. The indicated life cycle for the first generation is as follows: Incubation, 10 days; feeding period, 34 days; prepupal period, 2 days; pupal period, 10 days; from emergence to egg laying, 1 day; entire length of life cycle of first generation, 57.3 days.

Apparently eggs of the first generation begin hatching in the fore part of May and of the second generation about July 1. Whether all of the first-brood larvæ transform to moths the same season is not apparent from the information at hand. It seems fairly certain, however, that there is at least a partial second generation. There is evidently considerable overlapping of the two generations. Adults are emerging more or less throughout the summer and it is possible to find at almost any time larvæ of all sizes. Pergande, in 1898, records rearing one moth in the insectary at Washington from a larva sent to him from Anderson, S. C., as late as October 24, and the writer has observed newly hatched larvæ at Winchester September 28.

HIBERNATION.

In the late fall the larva constructs, under the bark scales at the entrance to its feeding galleries, a loose, light, but very tough cocoon of white silk. To the outside of this are often fastened frass and small pieces of bark. Numerous observations in the seasons of 1912 and 1913 indicate that many of the larvæ go into the winter in an immature state, yet in the spring of 1913 no evidences of feeding were found among about 100 larvæ collected in the field. All of the undersized specimens, of which there were a considerable number, proved to be parasitized. In 1912 newly hatched larvæ were found in the field as late as September 28, and in favorable years immature larvæ may succeed in passing the winter successfully in northern Virginia. In the writer's opinion, however, the mortality due to winter killing among the immature larvæ must be very high in this latitude.

When disturbed or exposed to the light the larva leaves its winter cocoon and spins up in a more protected place. However, as a rule, unless disturbed or unless the winter cocoon is located in an unsatisfactory place, the larva pupates in the same cocoon in which it passes the winter. Larvæ have never been observed passing the winter as "free larvæ," even parasitized specimens spinning a cocoon. In fact, even during the summer months the insect usually threads a light shelter at the end of its burrow where it rests when not feeding.

NATURAL ENEMIES.

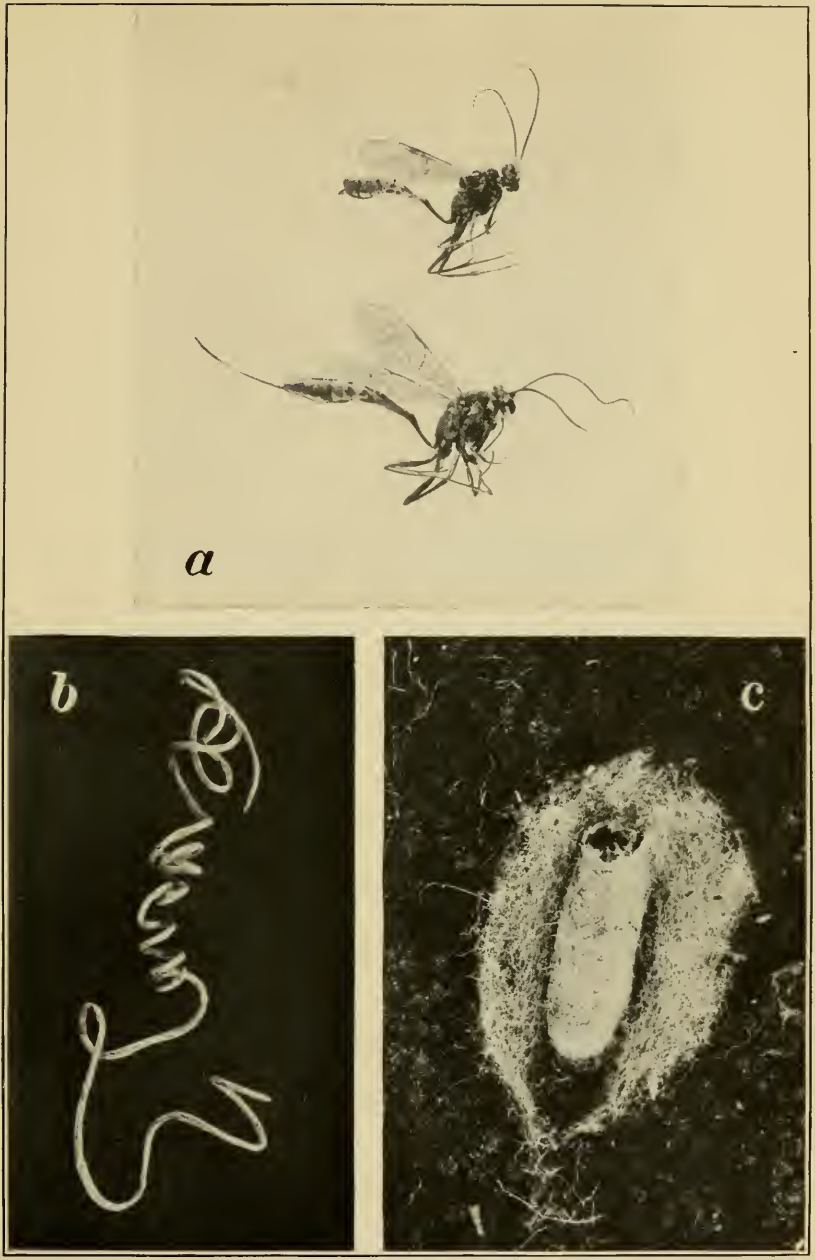
The larvæ of *Euzophera semifuneralis* are attacked by a number of parasitic and predaceous enemies. Two parasitic forms were reared at Winchester in 1913, which were determined by Mr. R. A. Cushman, of the Bureau of Entomology, to be *Idechthis* sp. (Pl. III, *a*) (Quaintance No. 10402) and *Mesostenus thoracicus* (Cress.). The former was by far the more common. Of 104 overwintering larvæ collected in the field 14 were parasitized by this insect. This proportion of parasitized specimens, amounting to 13.47 per cent, indicates that the parasite may aid very materially in the control of the borer. The parasitized larvæ are about one-half normal size and usually lack the greenish-brown color of healthy specimens. At some time during the prepupal period the parasite matures, devours the larva, and spins its cocoon (Pl. III, *c*). Fred Johnson, in 1905, at Youngstown, N. Y., reared an undetermined member of the family Ichneumonidæ (Quaintance No. 574). J. H. Beattie, in 1905, at Fort Valley, Ga., reared from borer larvæ *Itoplectis marginatus* (Prov.), *Mesostenus gracilis* Cress., and *Pimpla* sp. (Quaintance No. 399).

Mr. Fred E. Brooks, of the Bureau of Entomology, records rearing a hairworm, probably a species of Mermis (Pl. III, *b*), from larvæ of the plum borer.

Among the predaceous enemies the larva of *Tenebroides corticalis* Melsh. has been taken feeding upon the borer. Ants and woodpeckers are also important factors in reducing the numbers of this insect.

REMEDIAL MEASURES.

As has already been stated, the plum borer will probably never become a pest of more than ordinary importance, except in occasional isolated cases. Its food habits are such that it is entirely unable to establish itself upon vigorous, healthy, uninjured trees. However, in common with a number of other insects it does deserve some attention on account of its ability to do considerable real injury where the proper conditions are presented, i. e., where trees have been injured by hail, frost, or attacks of fungous diseases, and its rather indiscriminate choice of food plants increases its opportunities in this direction. One of the most common instances of this in the observation of the writer is in the case of the collar blight of apple, where the injury done by this disease is frequently supplemented by subsequent attacks of the plum borer. When the ordinary precaution of cutting away the dead bark and painting the wounded areas is followed, this may be regarded as sufficient for the control of the borer. Where the borer has established itself already the cutting-out method is the only one that can be followed. Nothing may be expected from the application of poisonous washes.



PARASITES OF THE AMERICAN PLUM BORER.

a, *Idecthis* sp., a common parasite of the plum borer; upper figure, male; lower figure, female; considerably enlarged; *b*, hairworm reared from larva of the plum borer in 1912 at French Creek, W. Va., much enlarged; *c*, cocoon of the parasite *Idecthis* sp. within the cocoon of its host, much enlarged. (Original.)

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No. 263

Contribution from Bureau of Entomology, L. O. Howard, Chief.
July 19, 1915.

(PROFESSIONAL PAPER.)

THE CRANBERRY ROOTWORM.[1]

By H. B. Scammell, *Entomological Assistant, Deciduous Fruit Insect Investigations.*

INTRODUCTION.[2]

The investigation of cranberry insects in New Jersey has included the biological study of a beetle, well known to collectors for more than a century, but unrecorded, until recently, as a pest to the cranberry. Attention was first called to it on the cranberry bogs by Mr. T. B. Gaskill, of New Egypt, N. J., who reported injury in a bog in his vicinity and sent specimens of larvæ, pupæ, and beetles to the Bureau of Entomology for determination. Adult specimens, submitted to Mr. E. A. Schwarz, were determined as *Rhabdopterus picipes* Oliv., of the family Chrysomelidæ.

Mr. A. L. Quaintance (1912),[3] of the Bureau of Entomology, after making a visit to the infested bog in June of 1912, presented his observations on the extent and character of the injury and the feeding and probable egg-laying habits of the beetle before the Entomological Society of Washington. These notes were the first published records pertaining to the economic importance of this insect.

Rhabdopterus picipes was first described by Olivier (1808) from the collection of Bosc in the Jardin des Plantes, Paris, being placed by him in the genus Colaspis. It was later described by Say (1824) under the name *Colaspis pretexta.* Le Conte, when he edited the writings of Say (1859), made note that *Colaspis pretexta* Say is *Colaspis picipes* Oliv. The genus Rhabdopterus was erected by Lefevre in 1885, and a few years later Horn (1892) transferred *picipes* from Colaspis to Rhabdopterus.

Later writers have made mention of the food plants of the beetle, but only one larval host is known. With the finding of the larvæ on cranberry roots and the dying of the vines in infested areas it was deemed advisable to devote special attention to the habits and

[1] *Rhabdopterus picipes* Oliv.; order Coleoptera, family Chrysomelidæ.

[2] The illustrations used in this paper are from photographs by Messrs. H. K. Plank and J. H. Paine, of the Bureau of Entomology. The author is also pleased to acknowledge the assistance of Mr. Plank in carrying on life-history studies of the cranberry rootworm.

[3] Bibliographic citations in parentheses refer to "Literature cited," p. 8.

distribution of the insect with a view to devising means of control, (1) by spraying, (2) by the use of water for flooding operations, and (3) by cultural treatment of the bogs. Observations continued through a period of two years indicate that at the present time the pest is not one of prime importance on cranberry bogs and that its ravages are not to be compared in severity with those of the cranberry girdler (*Crambus hortuellus* Hübn.) to which insect probably the injury produced by the rootworm has heretofore been attributed.

DISTRIBUTION.

The cranberry rootworm is widely disseminated throughout the United States and is also reported from Canada. Blatchley (1910) reports it in Indiana and further states that it occurs from Massachusetts to Dakota and south to North Carolina. In the collection of the Philadelphia Academy of Natural Sciences specimens are exhibited from Utah, Nebraska, Illinois, "Dakota," southwestern Texas, Florida, Delaware, Pennsylvania, New Jersey, and Canada. Smith (1909) lists it from New Jersey south of the Piedmont Plain. The present investigation has led to its capture on one or more cranberry bogs at or near the following places in New Jersey: Pemberton, New Lisbon, Whitesbog, New Egypt, Cookstown, Chatsworth, Pasadena, Medford, and Brookland.

FOOD PLANTS.

Few plants are recorded as hosts of the beetle. Say states that it is common on the myrtle, while Blanchard found it abundant on basswood. In Indiana it is reported on wild grape, and Smith lists it in New Jersey on myrtle, grape, and basswood. More recent observations have shown that the beetle is a feeder on foliage and fruit of the cranberry, and the writer has taken it on blueberry and inkberry by jarring. The larvæ are abundant on the roots of cranberry.

CHARACTER AND EXTENT OF INJURY.

The chief injury to the cranberry is caused by the feeding of the larvæ on the roots and runners (Pl. I, fig. 2), where the latter come in contact with the ground. As a rule only the bark is eaten from the large and secondary roots, the wood occasionally being attacked, while the fibrous roots (Pl. I, fig. 1), which are so numerous as to form a dense mat an inch or more in thickness, are completely devoured. The character of the rootworm injury is such that one can distinguish between it and the injury produced by the cranberry girdler. The larvæ of the latter insect prefer the runners and crowns of the plants and not only feed on the bark but devour the wood, often eating completely through a runner. In a general way it may be said that the rootworm feeds in the soil, while the girdler feeds on the surface, concealed in the trash which lies on the ground.

The vines which suffer the most are those growing on sandy land or what are usually termed "savannas." Larvæ have been found in

several instances in peat bottoms, where the roots of the vines may travel a foot in depth, but in these instances the dying of the vines could usually be traced to the feeding of the cranberry girdler.

When the root feeding is severe the vines show signs of weakening in the early fall. The leaves dry out, turn red or brown, and before growth starts the following season most of them will have shattered to the ground, leaving the dead uprights and runners bare of green foliage. Small areas are thus killed out, almost invariably at the margins of the bogs or on relatively high and sandy areas in the interior of the bogs. (Pl. II, fig. 1.) The mud and peat bottoms rarely suffer from rootworm attacks, presumably because the root system of the cranberry is so much thriftier and more extensive in these soils than in sand and possibly because the beetles seek sandy soil in which to deposit their eggs.

The injury produced by the feeding of the beetles on the foliage and berries is so slight as to be almost negligible. This habit, however, affords a means of control, namely, of poisoning their food by the use of insecticides.

DESCRIPTION OF STAGES.

THE ADULT.

The adult (Pl. II, fig. 3) is a shining brown beetle measuring less than one-fourth of an inch in length. The following description of the adult is taken from Blatchley; those of the other stages are by the author.

Oblong, oval, convex. Brown, bronzed, strongly shining, the elytral margin often greenish-bronzed; antennæ and legs reddish-yellow, the outer joints of former often dusky; under surface of body greenish, abdomen brown, its tip paler. Head coarsely and sparsely punctate, clypeus more closely punctate. Thorax nearly twice as wide as long, narrowed in front, sides strongly curved, hind angles prominent; disk rather sparsely and finely punctate, elytra coarsely but not closely punctate, the punctures irregular on the disk, a line representing the third interval smooth. Length 4–5 mm.

THE EGG.

The eggs (Pl. II, fig. 2) of the cranberry rootworm measure 0.67 mm. in length by 0.30 mm. in width. In shape they are regularly elongate, elliptical. When first deposited they are a dirty white in color, later becoming uniformly yellow. The shell is smooth and glistening, and sufficiently transparent to reveal the larval outline before hatching.

THE LARVA.

The full grown larva (Pl. II, fig. 5) measures from 7–9 mm. Normally it lies in a curved position so that its full length is seldom revealed. Its color is whitish with head light brown and thoracic shield of very pale yellowish brown. Tips of mandibles black, shading off to light brown at the base. Labrum and clypeus brown. A row of brownish spines, the ambulatory setæ, on each ventral abdominal segment projects obliquely backward. Setæ long. Legs slender and small.

THE PUPA.

The pupa (Pl. II, fig. 4) is slightly shorter than the extended larva, whitish in color. Spines on the head and thorax are longer and stouter than those in the larval

stage. The middle and posterior femora are each provided with one curved spine and two straight, more slender spines; two flattened hooklike spines, curving outward, are found at the posterior end of the abdomen.

LIFE HISTORY AND HABITS.

ADULT STAGE.

Emergence of the beetles from the soil begins about mid-June, the maximum number emerging in breeding cages June 28. This date will vary, however, depending upon the time of drawing the winter flood from the bog; as early as June 6 beetles in the process of hardening were taken from the soil whereas the latest capture of the season was made October 20. They are easily captured by sweeping the bog with a net and with more difficulty by searching in the fallen leaves and refuse which often form a layer of trash an inch or more in depth under the vines. The beetles go into the trash so that they may deposit their eggs in the soil, and to find them one must carefully turn over the litter. Some are on the vines; feeding usually on the new growth of foliage, which they attack from the outer margin. Others may be found on the small berries, gouging shallow furrows around the fruit. When disturbed they fly short distances, seldom more than three or four feet. A few cage experiments showed that the females are longer lived than the males, one female remaining alive 56 days.

EGG STAGE.

Eggs have been found in a cranberry bog lying in a mass just beneath the surface of the ground. In rearing cages they are most frequently deposited in masses but occasionally are found singly. The highest number found in one mass and known to have been laid by one female was 53 eggs. The average number of eggs per mass was 14. Caged beetles sometimes oviposited on the sides of the cage or on fallen leaves, but most frequently the eggs were inserted about an eighth of an inch in the soil. In a previous report on the cranberry rootworm the writer (1914) gave the length of the egg stage as 11 days. Further data show that this period varies from 6 to 11 days, averaging 8 days.

LARVAL STAGE.

The small larvæ find their food in the first inch or two inches of roots and soil and, owing to the fact that the fibrous roots are so abundant, it is presumed that the larvæ travel little in search of food. Larvæ may be found feeding at all times during the summer and until quite late in the fall, at which time some of them go deeper into the ground. November 17, Mr. H. K. Plank, of the Bureau of Entomology, found larvæ in a peat soil at depths ranging from an inch to 1 foot. December 1 the larvæ were found in the first 2 inches of a rather dry, sandy soil. When feeding ceases a round cell is formed in the soil within which the larva hibernates until spring. If the bog is flooded during the winter the larvæ remain dormant, at least until the winter

FIG. 1.—NORMAL ROOT SYSTEM OF THE CRANBERRY GROWN ON SAVANNA BOTTOM.
FIG. 2.—INJURY TO CRANBERRY ROOTS BY THE LARVÆ OF THE CRANBERRY ROOTWORM (RHABDOPTERUS PICIPES). (ORIGINAL.)

WORK OF THE CRANBERRY ROOTWORM.

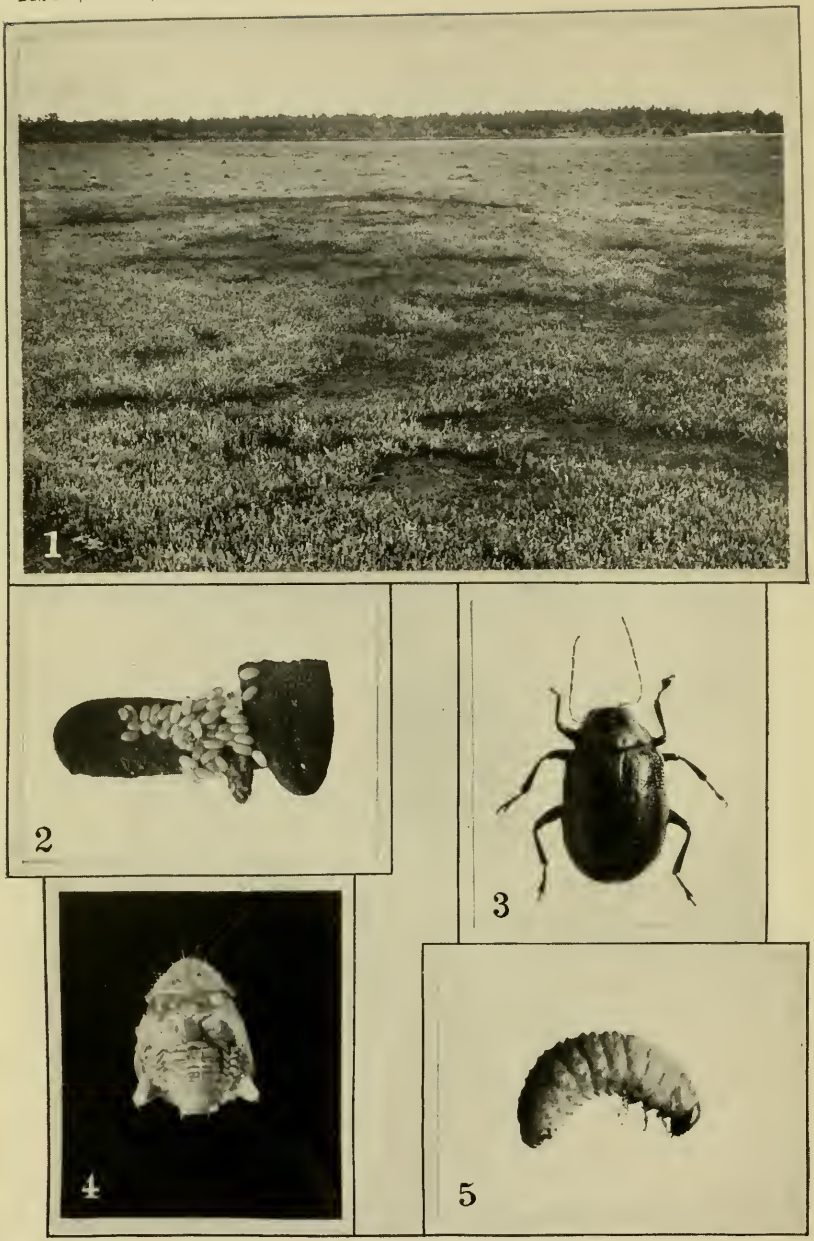

FIG. 1.—CRANBERRY BOG, SHOWING DEAD AREAS CAUSED BY THE LARVAL FEEDING OF THE CRANBERRY ROOTWORM (RHABDOPTERUS PICIPES). FIG. 2.—EGG MASS. FIG. 3.—ADULT. FIG. 4.—PUPA. FIG. 5.—LARVA. (ORIGINAL.)

THE CRANBERRY ROOTWORM AND ITS INJURIES.

flood is drawn in the spring. Soon after the water is drawn the larvæ commence to feed again, which may be noted by the fresh barking of the roots. Before commencing to pupate the larvæ move closer to the surface of the bog, the majority being found in the first inch of soil. Some idea of their abundance was obtained by counting the larvæ under plats of soil 10 inches square. Twelve larvæ were obtained in one instance and other counts of 11 and lesser numbers were made where the injury to the vines was quite apparent. From the foregoing it will be seen that the species spends most of its life in the larval stage, or approximately 10 months. Possibly some of the larvæ fail to mature at the expiration of this period and spend another year in the bog before reaching the adult stage.

PUPAL STAGE.

The time when pupation commences varies somewhat with the management of the bog. The earlier the flood is drawn the earlier will be the date of general pupation. In 1913, when the water was drawn April 1, pupæ were in the majority June 6; while in 1914, when the water was drawn May 20, the larvæ outnumbered the pupæ two to one on June 15. Pupation studies were carried on in wooden cages having glass bottoms, which permitted one to observe those larvæ which formed cells against the glass. The average duration of the pupal stage was found to be 14½ days, and from 2 to 3 days were spent by the adult hardening in the cell and reaching the surface.

SUMMARY OF LIFE HISTORY.

Stage.	Period of usual occurrence.	Range in occurrence.	Usual duration.	Range in duration.
			Days.	*Days.*
Adult	June 20–Aug. 1	June 6–Oct. 20	35	56
Egg	July 10–30	July 10–Sept. 3	8	6–11
Larva	July 16–June 1	All seasons (months)	10½	.....
Pupa	June 10–30	May 25–July 9	14½	13–17

RECOMMENDATIONS FOR CONTROL.

Some way in which to control an insect infestation by the use of water usually first suggests itself to one connected with the cranberry industry. The particular bog, however, upon which most of the observations were made has an insufficient water supply limited to a winter flooding with no available water for reflooding. Late holding of the water—that is, until May 20—had no effect in reducing the infestation. The larvæ were in as good condition after this treatment as when, the year previous, the water was drawn April 1. Laboratory experiments have shown that the larvæ can live submerged in clean water for as long as 41 days, while pupæ have not survived more than 9 days. Examination of a bog which had been reflowed for a period of 4 days in the latter part of May disclosed many live larvæ but no

dead ones. Another bog, in which the insects were found to have reached the pupal stage, was reflowed May 28 and 29 for a period of 27½ hours. Soon after the water was drawn from this bog a second investigation was made which revealed no dead pupæ and 49 live pupæ. Reflowing the bog when the beetles have emerged from the ground and before egg laying has commenced would undoubtedly carry some of the beetles ashore where they could be killed with kerosene, but this operation would have to come at a time when the young berries are forming, and the use of water at that time is apt to be disastrous to the setting of the crop.

Carbon bisulphid was given a trial to determine its effect on larvæ and pupæ in the soil. Used in holes at varying strengths of the liquid and varying depths and distances apart, negative results were obtained in each plat. In plat 1 the holes were made a foot apart and 4 inches deep and into each was poured one-half fluid ounce of carbon bisulphid. The liquid nearly filled each hole and all holes were covered with soil and tamped with the foot. Larvæ found within 2 inches of some of the holes were unaffected by the gas. The failure of this substance to kill is thought to have been due to the wetness of the bog which prevented the fumes from penetrating the soil. No injury resulted to the vines except where drops of the liquid were spilled on them from above.

Observations of two seasons' spraying on a bog near New Egypt, N. J., have shown that an arsenical, added to the customary Bordeaux and resin-fishoil soap used to control the fungous diseases of the cranberry, is of value in killing the beetles which feed on the foliage. Arsenite of lime at the rate of 1 pound of white arsenic per 200 gallons of Bordeaux mixture per acre was the poison applied by the owner of the bog the first year. Two applications were made, the first beginning July 1 and the second July 14. In 1914 the bog was sprayed more frequently owing to the presence of an infestation of fireworms (*Rhopobota vacciniana* Pack.). The dates of spraying were June 11, June 18, June 30, July 9, and July 20. Arsenite of lime was used in each instance, but beginning with the third application a different method of preparing it was employed, as follows—1 pound of caustic soda was dissolved in 2 quarts of water and while this was dissolving, 2 pounds of white arsenic were added. It is essential in preparing arsenite of soda after this formula that a very good grade of caustic soda be secured, otherwise some of the arsenic may remain uncombined and produce injury to the foliage or fruit. In five minutes the arsenic was completely dissolved, leaving a clear solution if the crystalline variety of arsenic was used, or a silt-colored solution if the amorphous arsenic was employed. The presence of a small amount of lead in the amorphous arsenic seemed to account for the cloudiness of the solution. Mr. F. S. Chambers, of J. J. White (Inc.),

New Lisbon, N. J., was the first to introduce this method of preparing arsenite of soda for use in the spraying of New Jersey cranberry bogs.

In the first two applications arsenic was used at the rate of $1\frac{1}{3}$ pounds per acre, the later applications being increased to 2 pounds per acre. Arsenite of lime, prepared and used as just described, is exceedingly cheap compared to arsenate of lead, but the dangers attendant upon its use by inexperienced help, both to human life and from possible injury to the foliage and fruit, are such that it is preferred to recommend arsenate of lead for general use. The latter insecticide is frequently used on cranberry bogs at the strength of 3 pounds of paste arsenate of lead to 50 gallons of water or Bordeaux mixture. If arsenite of lime is used as the insecticide, it is very essential that thorough agitation of the spray material be maintained. Some foliage injury, noted on three different bogs, should probably be attributed mainly to a neglect to keep the mixture agitated at all times when spraying. At the conclusion of the second season's observations no new areas on the sprayed bog were found infested and the number of larvæ throughout the bog had decreased to a marked degree.

Having observed on a number of bogs that the injury by the rootworm almost invariably occurs on sandy land and, further, that the root system of the cranberry on such land is exceedingly shallow as compared with that on peat or muck lands, it is fair to conclude that treatment of the bog by fertilizers to stimulate growth will be of great advantage to the cranberry plant in outgrowing the injury of the larvæ.

The New Jersey Experiment Station has amply demonstrated at Whitesbog, N. J., that weak vines on sandy soil can be made to produce an abundance of vines in one season by the application of the proper mixture of chemical fertilizers. It so happens that this land is infested with rootworms, but the extent of the infestation could not be definitely determined without tearing up the fertilizer plats more than is advisable. Some of the plats are known to be infested, but in spite of the presence of the rootworms the vines have made so much growth in two years that pruning would not be inadvisable.

Sanding infested areas also gives promise of being a satisfactory method of promoting vine growth. Mr. T. B. Gaskill, of New Egypt, N. J., has clearly demonstrated on a small, badly infested area of savanna land that a 1-inch coat of sand will cause the vines to grow vigorously, sending out runners which cover the bare spaces, and to present a marked contrast to unsanded adjacent vines.

SUMMARY.

The cranberry rootworm (*Rhabdopterus picipes* Oliv.) is the larva of a small brown beetle which has recently been found on a number of cranberry bogs in New Jersey.

It is widely distributed throughout the United States, but previous to its discovery on the cranberry it was not regarded as of economic importance.

The number of its known food plants is few.

The chief injury to the cranberry is produced by the feeding of the larvæ on the roots. The beetles feed on the foliage and fruit.

Its injury occurs mainly on sandy land or savannas, where the root system of the vines is not so extensive as on muck or peat bottoms.

The beetles appear in numbers about the end of June, deposit eggs in the soil, and die before fall.

The larvæ feed on the fibrous roots and bark of the larger roots until late fall, when they hibernate in cells formed in the soil.

Some spring feeding of the larvæ occurs.

Pupation commences early in June, the average duration of the stage being 14½ days.

No satisfactory practice in the use of the winter flowage or the spring reflowage to exterminate an infestation of larvæ or pupæ has been developed.

Invigorating the vines by the application of fertilizers or sand promises excellent results.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 262

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief.

Washington, D. C. July 19, 1915.

THE PARANDRA BORER AS AN ORCHARD ENEMY.

By Fred E. Brooks,

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INTRODUCTION.

During the past few years the larva of a medium-sized brown beetle, *Parandra brunnea* Fab., has attracted considerable attention as an enemy of trees of several widely separated species and of chestnut telephone and telegraph poles. The characteristic injury of the insect to trees is in the form of a multitude of tortuous larval galleries extending through a more or less restricted portion of the trunk or larger branches. The most destructive attacks usually occur in the trunk within a few feet from the ground, the work of the borers being followed quickly by the decay of the affected wood and frequently by the breaking down of the tree (Pl. I, fig. *a*) at the point of greatest injury. (Pl. I, fig. *b*.)

Cultivated fruit trees are often injured by this borer, old apple, pear, and cherry trees being especially liable to attack. Hollow bases and decaying areas and cavities in the trunk and the consequent breaking and falling of weakened trees under the pressure of wind and snow are conditions quite commonly due in a large measure to the work of this insect. Injury is especially noticeable to trees growing in sunny, exposed positions, and the insect seems to be rather more abundant about villages and cities than in country districts, although both the larvæ and adults are found in many dissimilar locations and under a variety of conditions.

Tree surgeons and other persons who attempt to save and rejuvenate fruit trees suffering from diseased and decaying trunks quite often encounter the Parandra borer and its work. In cleaning out

Note.—This bulletin describes the Parandra borer as an enemy of fruit trees, gives its history and distribution, and suggests methods of combating it. It will be of interest throughout the greater portion of the United States.

Note.—In Mr. Snyder's interesting article on this species as an enemy to chestnut telephone and telegraph poles (Bul. 94, Pt. I, Bur. Ent., U. S. Dept. Agr., 1910), the beetles are illustrated in Plate I, figure 1, and the male is shown as the larger of the two sexes. Mr. Snyder has discovered that this is an error and wishes us to add that the female is almost always larger, or at least as large as the male.

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old cavities in the trunk or larger branches for the purpose of filling with some cement-like material, a practice which is growing in favor, the presence of this borer often forces the operator, in removing all unsound wood, to cut much deeper into the tree than would otherwise be necessary.

While trees of medium age are sometimes attacked, and old trees that have been somewhat neglected suffer most, the borers have also been reported as occurring in nursery stock. Many old orchards that have passed their prime, but are still capable of producing good and profitable crops of fruit, are hastened to their end by this insect.

In two or three specific instances the Parandra borer has been recorded as being injurious to fruit trees, and many cases have been reported of the collection of the parent beetle on or about orchard trees. It appears, however, that no recommendations as to remedial measures have been made, and it would seem that further information regarding the insect and its habits and possible methods of reducing or preventing its attacks should be available to fruit growers and owners of fruit-producing trees. For the foregoing reasons this brief account of the species is presented.

HISTORY AND DISTRIBUTION.

The Parandra borer has been referred to by previous writers as the "ash root-borer," "chestnut telephone-pole borer," and "heartwood borer." These names, while significant with regard to the habits of the insect, are regarded by the writer as being too restrictive in their meaning to be appropriate as common names, since the borer does not confine its attacks to ash roots, chestnut telephone poles, nor entirely to the heartwood of trees in which it feeds. In fact, it is a very general feeder, attacking the live and dead heartwood and sapwood of a great variety of trees, including pine, black walnut, hickory, willow, beech, chestnut, chinquapin, oak, elm, tulip, apple, pear, plum, wild and cultivated cherry, locust, Ailanthus, soft maple, basswood, and black ash.

The Parandra borer belongs to the Spondylidæ, a small family closely related to the Cerambycidæ which includes many of the wood-boring larvæ. The species was first described by Fabricius,[1] in the year 1798, and given the technical name which it still bears. In the year 1861 Dr. George H. Horn [2] made the following record: "The larva of this insect may be seen in almost every locality in which decaying wood may be found. It appears to prefer beechwood, at least I have always found greater numbers in that particular kind of wood." In 1880 the American Entomologist for the month of August acknowledged the receipt by Dr. C. V. Riley of larvæ of this

[1] Fabricius, J. C. Supplementum Entomologiæ Systematicæ, p. 49. Hafniæ, 1798. *Tenebrio brunneus.*

[2] Horn, G. H. Observations on the habits of some coleopterous larvæ and pupæ. *In* Proc. Ent. Soc. Phila., v. 1, p. 43–44, Sept., 1861; p. 43, *Parandra brunnea* (Fabr.).

species, taken from black ash by Mr. Shelby Reed, Scottsville, N. Y. Various other writers give brief notes on the larvæ and adults as occurring in and about different species of forest trees, but it was not until the year 1890 that a note was published by Dr. F. H. Chittenden [1] of the Bureau of Entomology, associating the species with a cultivated fruit tree. In this note the author states: "found under the bark of domestic cherry; are very common." Mr. Thos. E. Snyder,[2] in 1910, writes that it has been determined that this beetle damages many species of living forest, fruit, and shade trees. In 1911, Mr. Charles A. Hart [3] published an account of this species in which he described the damage done to apple and other trees.

The insect has been found in Ontario, Canada, and in the States of Connecticut, New York, New Jersey, Pennsylvania, Illinois, Minnesota, Maryland, Virginia, West Virginia, Arkansas, Texas, Arizona, and California, and in the District of Columbia. There is little doubt that it may be found over the greater part of temperate North America.

CHARACTER OF INJURY.

The Parandra borer is one of several species of borers from which trees are in very little danger of injury so long as they are kept in sound and vigorous condition. The borers of the present species enter the wood from dead or decaying places on the surface (Pl. II, figs. *a*, *b*) and are probably never found in trees whose trunks and larger branches are entirely covered with healthy bark. Any accident or condition that will produce dead or decaying surface areas, especially about the base of the trunk, may result in a severe infestation by this borer, and, ultimately, in the loss of the tree. (Pl. I, fig. *a*.) Bruises on the trunk made by singletrees or farm tools; cavities resulting from improper pruning; areas killed by winter injury, sun scald, fire blight, collar rot, flatheaded borers (*Chrysobothris femorata* Fab.) and roundheaded borers (*Saperda candida* Fab.) are some of the primary injuries that may result in attacks by the Parandra borer.

When a tree is first attacked the beetles insert their eggs into the surface wood of the dead spots, usually after more or less decay has progressed, and the larvæ or borers extend their burrows throughout the adjacent heartwood and occasionally into the surrounding live sapwood. The borers mine throughout the wood for a period of probably three years, extending their galleries upward more frequently than downward, and finally transform to beetles within the

[1] Packard, A. S. Fifth Report of the U. S. Entomological Commission. Washington, 1890. P. 223. "*Parandra brunnea* Fabr. Under bark. (Chittenden.)"; p. 530, "Found under bark of domestic cherry, are very common."

[2] Snyder, T. E. Damage to chestnut telephone and telegraph poles by wood-boring insects. U. S. Dept. Agr., Bur. Ent., Bul. 94, Pt. I, p. 6, Dec. 31, 1910.

[3] Hart, C. A. The heart-wood borer (*Parandra brunnea* Fabr.). *In* 26th Rpt. Ill. State Ent., p. 68-73, figs. 5, 1911.

wood. These beetles work their way out through the larval galleries or gnaw through the dead wood to the surface and escape. They return frequently to the dead wood, however, and spend much time hiding in secluded spaces, such as old galleries, within the injured tree. Eggs are now inserted into the wood that forms the walls of the old burrows (Pl. III, figs. *a*, *b*), and the borers of the new brood penetrate still farther into the wood. Other insects and fungi soon appear to accelerate decay, and within a few years that particular part of the tree will consist merely of a thin shell of sound wood surrounding a decomposed heart. A tree so affected may continue to live but will be in danger of falling under a load of fruit or during a storm at any time. The period of usefulness and the lives of many old trees too often terminate in this way.

The work of the Parandra borer is sometimes confused with that of the roundheaded apple-tree borer, but a little knowledge of the habits of the two species will enable anyone to distinguish quite readily between them. The two borers bear a general superficial resemblance to each other, but the differences in their methods of attacking trees are distinct. The Parandra borer enters at a dead spot or cavity and throws no castings to the surface, whereas the roundheaded apple-tree borer enters living wood and freely extrudes reddish-yellow castings, which form in small heaps at the base of the infested tree. The different positions habitually occupied in the tree by the two borers will serve as a better means of identification than any characters possessed by either while in the larval stage. The Parandra borer is slightly more slender and has three pairs of small but rather distinct thoracic legs, while the roundheaded apple-tree borer is legless. The adults of the two species are totally unlike in appearance.

LIFE HISTORY.

The adult Parandra borer (Pl. IV, fig. *a*) is a somewhat flattened, glossy, chestnut-brown beetle which is rather variable in size but averages slightly less than three-fourths of an inch in length. The beetles appear on the wing in July and August, the time depending considerably on the latitude. At French Creek, W. Va., the writer found that pupation took place during the last days of June and first days of July in the years 1913 and 1914, and that the adult stage was reached before the 1st of August by each of about 50 individuals kept under observation during that period. The adults remain in the pupal chamber for a week or 10 days and may then continue to stay within the decaying wood of the host tree for a further period before taking flight.

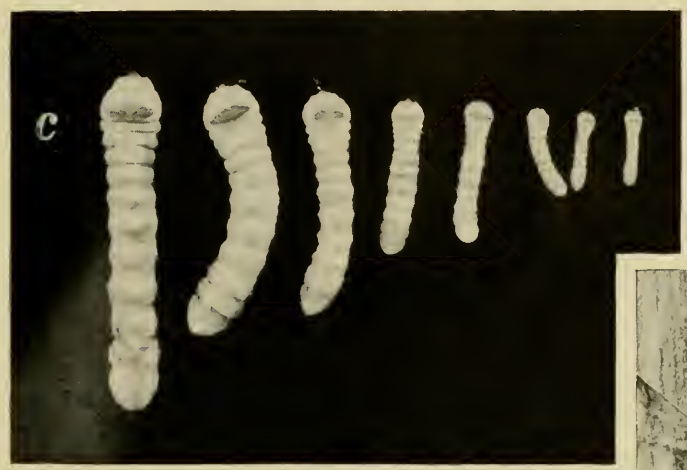
Egg laying begins soon after the beetles quit the pupal chamber. In placing her eggs the female makes small punctures in the wood, probably by the use of both her mandibles and ovipositor. These

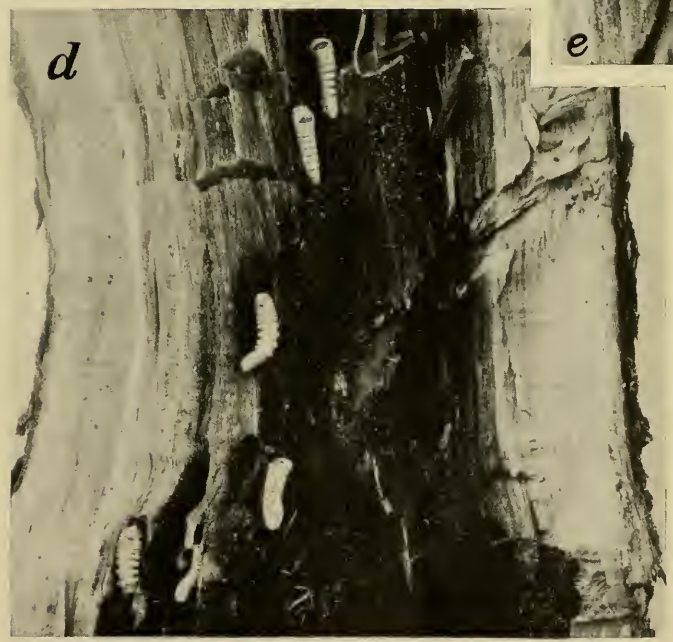
WORK OF THE PARANDRA BORER (PARANDRA BRUNNEA).

FIG. *a*.—Old apple tree broken in storm as a result of injury to the heart by Parandra borers. FIG. *b*.—Apple tree with heartwood and sapwood honeycombed by Parandra borers. (Original.)

ORCHARD CONDITIONS FAVORING THE PARANDRA BORER AND REMEDY.

FIG. *a*.—Section of apple trunk showing favorite place of entrance for Parandra borers. FIG. *b*.—Cavity in trunk of apple tree, formed by the decaying of a dead limb; suitable place for Parandra beetles to deposit eggs. FIG. *c*.—Cavity shown in *b* cleaned out preparatory to filling with cement. (Original.)





STAGES OF THE PARANDRA BORER.

FIG. *a*.—Egg of the Parandra borer in natural position. Natural size. FIG. *b*.—Eggs of Parandra borer in natural position in the wood of apple. Much enlarged. FIG. *c*.—Parandra borers; variety of sizes to be found in an infested tree at any one time. Natural size. FIG. *d*.—Parandra borers working into heart of apple tree from old wounds made by the roundheaded apple-tree borer, *Saperda candida*. FIG. *e*.—Group of galleries made by young Parandra borers just after leaving the egg. Natural size. (Original.)

STAGES OF THE PARANDRA BORER AND ITS PARASITE.

FIG. *a*.—Adults of the Parandra borer. Much enlarged. FIG. *b*.—Pupæ of *Parandra brunnea* in natural position in wood of apple tree. Natural size. FIG. *c*.—Larva and cocoons of *Odontomerus mellipes*, a parasite of the Parandra borer. Natural size. (Original.)

punctures are about 2 mm. deep by 1–2 mm. wide, and a single egg is placed in each. (Pl. III, fig. *a*.) After the egg is inserted the mouth of the puncture is closed with fine particles of wood. Eggs are deposited in this manner in groups of a dozen or less, placed close together, in either the solid or somewhat decayed wood which forms the walls of larval galleries or other openings in the tree where the beetles can enter. When trees are first attacked the eggs are probably inserted from the surface into the wood of dead areas.

The egg (Pl. III, fig. *b*) is 1.5 mm. long by 0.5 mm. wide, oblong-ovate, and creamy white. The surface is slightly granular. Eggs hatch in two or three weeks, the time not having been definitely determined.

As soon as the larva or borer (Pl. III, fig. *c*) hatches, it begins to feed away from the original position occupied by the egg and extends its gallery in a zigzag course through the wood (Pl. III, fig. *e*). With the exception of the head, which is black, the borer is yellowish white, but the body contents when feeding in dark-colored wood give it a darker appearance. When full grown the larva attains a length of about 1¼ inches. It grows slowly and probably remains in the tree for at least three years before changing to the beetle, although this point in the insect's life history has never been fully determined.

The galleries are packed throughout their length with dustlike particles of wood that have passed through the digestive canal of the borer. These galleries wind about in every direction and are usually so numerous as to honeycomb the wood of the affected part of the tree. (Pl. I, fig. *d*.) A single burrow may be several feet in length, but its course is so tortuous that it seldom extends at any point more than a foot away from the place where the egg was deposited. The usual general course is more or less directly into sound wood from a place that is beginning to decay. This results in a rapid enlargement of the area of decay and in the continuous extension of the infested area with the appearance of each successive generation of borers. In many infested trees examined by the writer the Parandra borer was found to have been the first agency to open the way for the spread of decay into heartwood. Other insects follow but less frequently precede them in their attacks on the heartwood of fruit trees.

When the larva is ready to pupate it excavates a cell at the terminus of its burrow in the heartwood large enough to accommodate its body. Within this cell it transforms to the pupal stage (Pl. IV, fig. *b*). The burrow is packed for a short distance next to the cell with coarse, stringlike fragments of wood. This excelsior-like material forms the bed on which the pupa reposes and is evidently provided to insure the drainage of any moisture that might otherwise

collect about the insect during the inactive period of pupation. The pupal stage is from 10 days to 2 weeks in duration.

As has been stated (p. 4) the adults appear in July and August. The writer's observations indicate that the beetles are rather short lived, although Snyder [1] believes that oviposition may continue from August to October, and Hart [2] mentions a specimen collected in Illinois on September 25. The beetles are somewhat sluggish and fly at twilight, perhaps extending their activities throughout the night.

NATURAL ENEMIES.

In the year 1880 Riley [3] mentioned an ichneumon fly belonging to the genus Pimpla as parasitic upon the borers of this species. The writer has found the hymenopterous parasite, *Odontomerus mellipes* Say[4] (Pl. IV, fig. *c*), attacking the Parandra borer in West Virginia. This latter parasite destroys the borer and then constructs an elongate cocoon of white silk within the burrow of the host, in which it changes to the adult form.

The Biological Survey has found this beetle in the stomach of the olive-sided flycatcher (*Nuttallornis borealis*).

REMEDIAL MEASURES.

The first and most important consideration relative to preventing injury to trees by the Parandra borer is the keeping of the trees in such a condition of soundness that the beetles will not deposit eggs in them. As has been pointed out (p. 3), the entrance of the borer into the tree is first made at some point where dead wood is exposed by the removal or decay of bark as a result of some mechanical injury or disease. If exposed dead surfaces can be prevented, the danger of attacks from this borer will be eliminated. Injury to the trunks or larger branches of fruit trees, affording favorable places for borer attack, result from a variety of causes, some of which at least are easily preventable. The practice which is not uncommon of leaving stubs 6 inches or more in length in pruning out large branches is quite likely to result ultimately in injury from this insect. The stubs left are practically sure to die back to the trunk and form a decayed spot or cavity that is exactly to the liking of the beetle as a place in which to oviposit. (Pl. II, figs. *a*, *b*.) Instead of leaving such stubs when removing large branches, the cut should be made near to the trunk where the natural swell at the base of the branch will insure healing to be most rapid. The cut surface should then be covered with a heavy coat of white lead or some similar paint.

[1] Snyder, T. E. Damage to chestnut telephone and telegraph poles by wood-boring insects. U. S. Dept. Agr., Bur. Ent. Bul. 94, Pt. I, p. 3, Dec. 31, 1910.

[2] Hart, C. A. The heartwood borer (*Parandra brunnea* Fabr.) *In* 26th Rpt. Ill. State Ent., p. 72, 1911.

[3] Riley, C. V. Ash-root borer: Supposed eggs of *Odontota*. *In* Amer. Ent., v. 3 (new ser., v. 1), no. 8, p. 202, August, 1880.

[4] Specimens of this parasite were very kindly determined by Mr. J. C. Crawford, of the U. S. National Museum.

Another common place of entrance for the Parandra borer is near the surface of the ground where injury has been done some time previous by the common roundheaded apple-tree borer.[1] (Pl. III, fig. *d*.) Such injuries by roundheaded borers often persist as unhealed wounds and are always a source of danger to the tree. If the roundheaded borers are found and removed while they are yet small, the wounds made by them will heal quickly and no danger from attack by Parandra borers will follow. Injuries to the trunks of trees by tools in the hands of careless workmen are possible places for future attacks by Parandra borers and should, of course, be avoided wherever possible. Where such injuries occur they should be cleaned of torn and splintered bark and wood and the surface thoroughly painted.

Winter injuries and diseases attacking the trunk are less easily preventable, but where these are present Parandra borers may be kept out at least temporarily by a liberal use of paint applied to the dead surfaces. Paints so used should be renewed as often as once a year, and the applications may well be made in the spring or early summer.

Whenever borers of this species gain entrance to a tree there is only one practicable way of removing them, and that is to gouge or chisel out all the wood through which their burrows extend. (Pl. II, fig. *c*.) The cavity should then be properly cleaned and disinfected and filled with cement. Wherever the borers are present at all they are likely to occur in considerable numbers, and it is their habit in feeding to scatter about through the wood so much that little can be accomplished by attempting to remove them with a knife and wire, as is often done with some other species of fruit-tree borers.

In chiseling out the borers preparatory to using cement, all the punctured wood and all the wood soaked with water or affected by decay or disease should be removed. The interior of the cavity should then be sterilized by applying creosote with a brush, after which it should be painted with a heavy coat of coal tar. The cavity should then be filled compactly with a mortar made of one part of a good grade of Portland cement and three parts of clean, sharp sand.[2]

Trees treated thoroughly in this manner will be practically safe against Parandra borers until new places of attack are formed. However, it is less expensive and more satisfactory in every way to keep trees so far as possible in such a condition of soundness that the borers will find no place to enter.

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[1] *Saperda candida*. It is interesting in this connection to note that Dr. F. H. Chittenden, of the U. S. Department of Agriculture, found Parandra borers working on a linden tree on the grounds of the U. S. Department of Agriculture on April 27, 1909, that had apparently entered the tree at a point previously injured by *Saperda vestita*.

[2] Collins, J. F. Practical tree surgery. *In* U. S. Department of Agriculture Yearbook for 1913, p. 163–190, pl. 16–22, 1914. Contains excellent directions for the use of cement in trees.

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 264

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. June 15, 1915.

THE VIOLET ROVE-BEETLE.

By F. H. CHITTENDEN, Sc. D.,
In Charge of Truck Crop[1] *and Stored Product Insect Investigations.*

INTRODUCTION.

Beginning with the year 1901 a small dark-colored rove-beetle, known to science as *Apocellus sphaericollis* Say, has been reported as an enemy to violets and other succulent ornamental plants in the District of Columbia and from St. Louis, Mo. This insect is a very common one in the United States and is quite generally known as a scavenger, feeding on humus and decaying vegetation and similar matter. That it feeds on violets as well as on a variety of other vegetation is now undoubted. Informants have furnished abundant proof of this in the eaten flowers and leaves, while beetles in confinement in the writer's laboratory were observed by him to attack violets and other plants. Nor does the insect confine itself to plants grown indoors or in gardens, since in its Washington occurrence the violets were grown in hothouses and at St. Louis the various plants affected were growing in the open. There is no doubt, however, that although the habit of the insect of feeding on delicate flowers and leaves is well established it is nevertheless an acquired taste, the insect living normally like others of its kind on old, dead leaves or in soil which has been covered by leaves over winter.

Undoubtedly injury by this species is more extensive than our notes show. This may be ascribed mainly to the resemblance of this insect, to the casual observer at least, to an ant, and to the fact that the beetles swarm in numbers on plants in the manner of ants. The year after the first report of injury by this species so many complaints of injuries by ants in greenhouses were made that the Florists' Exchange[2] asked the writer for an article bearing upon this subject.

[1] A large proportion of the insects which infest the garden also infest greenhouses, as in the present instance. Next to roses, violets are favorite flowers grown in this and some other countries. In Bulletin No. 27, new series, Bureau of Entomology (out of print, but available in libraries), a somewhat comprehensive publication on violet insects was furnished.

[2] F. H. C. A violet pest. *In* The Florists' Exchange, v. 36, No. 23, p. 1216, Dec. 6, 1913.

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It now seems probable that in some of these cases the rove-beetle might have been the culprit. The complaints cover scatteringly a span of 12 years.

It has been hoped that something more definite than is recorded concerning the life history of the insect could be learned before publication. The notes now presented, however, show conclusively the injurious character of the insect, and the remedies advised and used have proved perfectly successful, showing that it is not by any means a difficult insect with which the gardener or florist has to cope.

DESCRIPTIVE.

The ant which this beetle especially resembles is known as the pavement ant (*Tetramorium caespitum* L.). This ant often occurs in greenhouses, but when the two insects are carefully compared the much larger antennæ, or "feelers," of the beetle will readily be noticed.

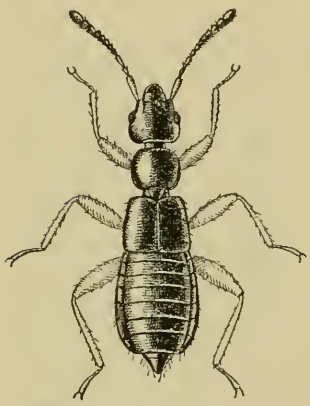

FIG. 1.—The violet rove-beetle (*Apocellus sphaericollis*): Adult. Greatly enlarged. (Original.)

Apocellus sphaericollis belongs to the group Oxytelini of the family Staphylinidæ, and is the sole representative of its genus occurring in the United States. It was originally described by Say in 1834, under the name of *Lathrobium sphaericolle*. The general appearance of the insect is shown in the accompanying illustration (fig. 1). The head is only slightly larger than the thorax, which is somewhat rounded. The elytra or wing covers are very short, as is usual in typical Staphylinidæ. The femora or thighs are larger than those of ants, but this is not noticeable at a distance when the insects are at work. The total length of the insect is about 2.5 millimeters.

October 14, 1901, Mr. L. J. Barber, Wheeler Road, near Congress Heights, Washington, D. C., brought living specimens of this rove-beetle, with report that it was injuring violets grown in hothouses, particularly low-growing forms, but did not attack the high-growing plants. He was positive that the beetles destroyed the flowers by riddling them with holes, and in response to inquiry thought it quite probable that they were introduced in manure that he was using.

Injury was thought, both by Mr. E. A. Schwarz, of the Bureau of Entomology, who furnished the identification of the species, and by the writer, to be due to some other insect, but Mr. Barber stated otherwise.

Two days later he brought specimens of the beetles with single-flowered violets which had not previously been attacked. Some of these already showed injury by the beetles. The chief injury was to the Marie Louise double violets, which grow with the flowers resting on the ground, and to Campbell double flowers, which are on the ground in their early stage but afterwards become erect. It seems that the beetles crawl directly from the ground to the flowers, and this accounts for the single-flowered varieties being free from infestation. No part of the plant other than the flowers was injured or attacked, so far as could be ascertained.

August 14, 1905, Mr. G. Pauls, St. Louis Altenheim, St. Louis, Mo., sent a specimen of this rove-beetle, which he stated was the greatest plant destroyer of the year at the Altenheim. The plants affected included lilies, dahlia, pansy, forget-me-not, and other soft plants, which were destroyed. The beetles were described as occurring everywhere, but preferring a low or mulch soil, especially under fallen leaves. September 9, 1905, he sent additional specimens with a plant of portulaca, which they were attacking. In his pansy beds, which they had completely ruined, the chickweed and yellow wood sorrel were not troubled. Portulaca seemed to be a favorite food.

November 21, 1913, the Florists' Exchange of New York furnished specimens of this insect on violets, requesting the name of the insect and asking what could be done to remedy the evil. Exact locality was not furnished.

REMEDIES.

Acting by the writer's advice, Mr. Barber used decaying leaves, deposited in piles at regular intervals about infested violet plants. This attracted the rove-beetles, after which the leaves were quickly dipped into hot water, which killed the insects, the leaves afterwards being restored as traps.

Four years after the first occurrence of this insect on hothouse violets it had disappeared as a pest, Mr. Barber reporting that he had used spinach, kale, and chickweed as traps, as advised. The same year Mr. Pauls reported that he had been successful in ridding his garden of this pest, at least on three of his pansy beds, by dusting them with tobacco. As a rule he could find no more rove-beetles, although in adjoining beds they were nearly as plentiful as before treatment. This report was received September 20, 1905.

There can be little doubt that injury by this species might be prevented by care in looking over the soil, or the dead leaves used as a mulch in violet or pansy beds, for the presence of the insect. Sterilization of this material before using would result in the destruction of the insect and prevent its introduction into the greenhouse or flower beds.

It might be added that it is fortunate that we can control this insect by comparatively simple means, since it is not desirable to fumigate violets when they are in bloom. Nicotine extracts are practically impossible, because of the more or less permanent odor which would obliterate that of the violets, and it is equally obvious that the use of arsenical sprays would be inadvisable.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1915

DIV. INSECTS

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 265

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER December 29, 1916

THE DOCK FALSE-WORM: AN APPLE PEST.

By E. J. Newcomer,

Scientific Assistant, Deciduous Fruit Insect Investigations.

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INTRODUCTION.

The dock false-worm is the larva of an allantine sawfly (*Ametastegia glabrata* Fallén) which may be called the dock sawfly. It has long been known, both in Europe and America, as an enemy of dock, sorrel, and knotweed, all common and sometimes troublesome plants which are to be found growing in moist places everywhere. Its acquired habit of boring into mature apples on the tree, to hibernate, thereby destroying their market value, brings it into prominence as an economic pest and has been noted by several observers in this country. Fletcher, in 1903 (30, 31)[1] and 1904 (33), reported finding the larva of a sawfly, which proved to be this species, boring into apples in Ontario in rather large numbers, and R. L. Webster (36) mentions the presence of these green worms in apples from New York, in 1908. Prof. A. L. Melander, of the Washington Experiment Station, in a letter to the Bureau of Entomology, under date of November 1, 1912, reports having known of the fruit-burrowing habit of this larva in British Columbia and since 1903 in Washington, particularly at Lynden, Whatcom County, where the injury amounted to about 10 per cent.

[1] Figures in parentheses refer to Bibliography, p. 38–39.

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In the fall of 1914 the writer's attention was called to a number of apples which had been perforated in one or more places, the holes being round, about 2 millimeters in diameter, and similar in appearance to those caused by an apple stem or by the apple falling on alfalfa stubble. These holes, however, were evidently the work of an insect. On cutting open these apples, one or more bright-green worms were found in each, in the burrows extending from the entrance holes. These larvæ were not feeding but were lying dormant, as though intending to pass the winter here. They appeared to be the larvæ of a sawfly, and, on looking up the literature, it was found that the larvæ of the dock false-worm were known to bore into apples occasionally. Adults were secured the following spring and definitely determined by Mr. S. A. Rohwer as *Ametastegia glabrata* Fallén. A visit on September 30, 1914, to the orchard from which these apples came, which is situated along the Entiat River, a tributary of the Columbia River in north-central Washington, showed that the injury from these larvæ was of some importance, about 2 per cent of the early apples, Jonathans and King Davids, being injured. This amounted to considerably more than the injury caused by the codling moth, which is as yet uncommon in this valley. Dr. A. L. Quaintance, entomologist in charge of Deciduous Fruit Insect Investigations, suggested that a study of the insect be made, and accordingly a number of infested apples were kept over the winter. Early in the spring the orchard was again visited, and several hundred hibernating larvæ, which had burrowed into the alfalfa stubble on the ground, were collected. With this abundant material a study of the life history and habits of this insect was begun, and the results form the subject of this paper. The writer is indebted to Mr. S. A. Rohwer, of the Bureau of Entomology, for suggestions and information regarding this species, and to Mr. Frank E. Knapp, of Entiat, Wash., for permission to carry on observations and control experiments in his orchard.

HISTORY.

The dock false-worm has been known for more than a hundred years, the adult having been originally described in Sweden by Fallén (1), in 1808, as *Tenthredo glabrata*. It was subsequently described under several names and placed in several genera in Europe, as shown in the synonymy below. The larva appears to have been first recognized by Kaltenbach (6) in Germany in 1859. The adult insect was originally described in America in 1862, by Norton (8), as *Taxonus nigrisoma*, and this name has been generally used in this country, although the name *Strongylogaster abnormis* was also applied to the species by Provancher (22) in 1885. The larva was first noted here by Jack in 1893. In a recent paper by Rohwer (37), it is considered that the European and American species are identical, and therefore,

according to the laws of priority, the specific name *glabrata* Fallén should be used, and the species belongs in the genus *Ametastegia*. The synonymy, as worked out by Rohwer, is given below:

AMETASTEGIA GLABRATA (Fallén).

Tenthredo glabrata Fallén, Svensk. Vet.-Akad. Handl., p. 108, 1808.
Tenthredo (*Allantus*) *agilis* Klug, Magaz. Ges. Naturf. Fr. Berlin, viii, p. 208, 1814.
Tenthredo (*Allantus*) *rufipes* Lepeletier, Monog. Tenthred., p. 81, 1823.
Ametastegia fulvipes A. Costa, Rendic. Acad. Sc. Napoli, xxi, p. 198, 1882.
Taxonus nigrisoma Norton, Proc. Boston Soc. Nat. Hist., ix, p. 119, 1862.
Strongylogaster abnormis Provancher, Addit. Faun. Can. Hym., p. 10, 1885.

DISTRIBUTION.

The dock false-worm is widely distributed in both Europe and America. In Europe it has been found as far north as Lapland, in northern Russia, and as far south as Italy. It is also recorded in the literature from Scotland, Sweden, Russia, northern Germany, southern Bavaria, Holland, and France.

In America the dock false-worm appears to be confined to Canada and the northern part of the United States. Provancher and Fletcher have observed it in Ontario, the latter having found the larvæ burrowing into apples. Norton's description of *Taxonus nigrisoma* is from specimens taken at Dorchester, Mass., and Jack found the larvæ at Jamaica Plain, both just south of Boston. From the other articles which have appeared concerning this species, and from the specimens in the National Museum collection, the following additional localities are taken: Stratford, Conn. (Walden), New York City and Flatbush, L. I. (Dyar), Seacliff, L. I. (Banks), Sherbrooke, Quebec, Harrisburg, Pa. (Myers), Menominee, Mich. (Chittenden and Titus), Ames, Iowa (Webster), and Minnesota (Ashmead collection). In the West the writer has found it very abundant in north-central Washington, at Wenatchee and Entiat, in Chelan County, and Prof. Melander reports it from Lynden, Whatcom County, Wash., from Kittitas County, Wash., and from British Columbia. It is very probable that the species has an almost continuous distribution in America from the Atlantic to the Pacific. It has never been recorded south of 40° north latitude, either in Europe or America, although some of its food plants are found farther south.

It is probable that the dock false-worm is distributed chiefly when in the prepupal or pupal stage in the dry stems of plants, for it is well protected here and during the winter season is to be found in these stems for a period of six months or more. The stems and stalks are very likely to be carried about in hay, packing materials, etc. In the egg and active larval stages the insect is greatly dependent on the fresh leaves of its food plant, and the adults, though active, are not strong flyers; thus it is not possible for the insect to travel far in these stages.

FOOD PLANTS.

The dock false-worm probably confines its feeding almost entirely to plants belonging to the buckwheat family (Polygonaceæ), including the numerous docks and sorrels (Rumex), the knotweeds and bindweeds, or wild buckwheat (Polygonum), and others. It has been recorded from *Polygonum bistorta* in Scotland, and from *Polygonum* sp., *Persicaria* sp., and *Rumex* sp. in Germany. In America it has been recorded from the common knotweed (*Polygonum lapathifolium* and *P. muhlenbergii*), and from a yellow dock (*Rumex patientia* or *brittanicus*). The writer has taken it on *P. lapathifolium*, on bindweed or wild buckwheat (*P. convolvulus*), on sheep sorrel (*Rumex acetosella*), on curly dock (*R. crispus*), bitter dock (*R. obtusifolius*), and willow dock (*R. salicifolius*). It was also found by Chittenden and Titus (34) feeding on the leaves of the sugar beet (Chenopodiaceæ), in a field where it had evidently consumed all of the dock and was forced by hunger to feed on this plant. The common cultivated buckwheat and rhubarb belong to the Polygonaceæ and may very well be food plants of this insect, though it has never been recorded from them and the writer has not had the opportunity of testing them.[1]

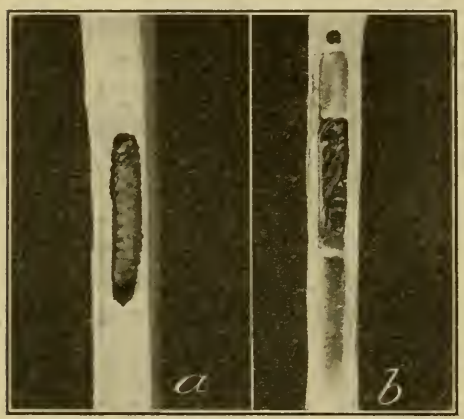


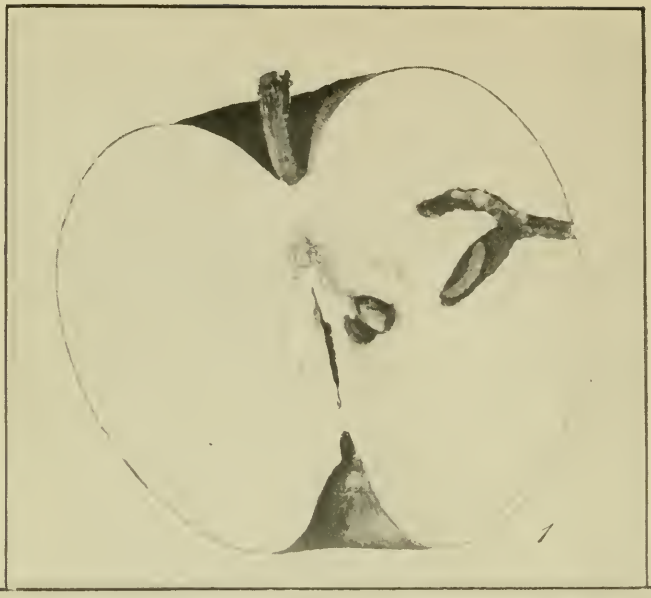
FIG. 1.—The dock false-worm (*Ametastegia glabrata*): *a*, Larva in hibernation cell in stalk of the dock plant; *b*, pupa of dock false-worm in larval hibernation cell. Enlarged. (Original.)

Several European writers have recorded a number of plants, not belonging to the buckwheat family, as food plants, but most of these are doubtful. Brischke (21) mentions loosestrife (*Lythrum salicaria*), and the common pansy (*Viola tricolor*). He was probably mistaken about the latter, in view of the fact that the larvæ of several related sawflies are known to feed on both the pansy and the violet. Kaltenbach (14) mentions goosefoot (*Chenopodium album*) and Laboulbène (16) mentions a reed (*Arundo phragmites*), but a careful reading of their papers shows that they merely found the prepupal larvæ in the stems of these plants, which does not necessarily indicate that they are food plants, as the full-grown larva will bore into any suitable stems, or even rotten wood or soft bark. Kleine (35) found

[1] In the summer of 1916, leaves of the common rhubarb and those of a wild species of Eriogonum were tested as food for the false-worm larvæ. A number of larvæ of different ages were provided with these leaves, and fresh food was supplied daily. The larvæ fed to some extent, but in a few days all had died, and it seems apparent that the leaves of these plants do not form a suitable food for this insect.

THE DOCK FALSE-WORM (AMETASTEGIA GLABRATA).

FIG. 1.—Leaf of dock plant (*Rumex crispus*), showing eggs of dock false-worm in situ. FIG. 2.—The dock false-worm and its injury to foliage of the dock plant; 6th instar larva on the left; on the right, 5th instar larva. FIG. 3.—Adult of dock false-worm on dock leaf. (Original.)



THE DOCK FALSE-WORM.

FIG. 1.—Larval hibernation burrow in mature apple. FIG. 2.—Injury to apples by dock false-worm, and rotting of fruit following injury. (Original.)

larvæ in the stalks of the orache (*Atriplex nitens*), and he states that the larvæ had undoubtedly fed on the pith, though he did not see them doing so, and did not find them feeding on the foliage. The writer has reared over a hundred and fifty larvæ, and has seen them bore into pithy stems, but in no case has he observed the last-stage larva feeding on the pith or on anything else. The borings are invariably pushed past the larva and fill up the burrow behind it. (Fig. 1, *a*.)

In the course of the work with the dock false-worm, larvæ and adult males and females were confined with plants of the common garden beet, with goosefoot (*Chenopodium album*), and with alfalfa, since many prepupal larvæ had been found in dry alfalfa stems. The adult females in every case died without ovipositing, and the larvæ died without feeding on any of the plants, although larvæ transferred from one known food plant to another, as from dock to wild buckwheat, readily adapted themselves to the change.

In feeding on any of these plants, the larvæ devour the leaf tissue and the smaller veins, eating out irregular holes in the leaves. (Pl. I, fig. 2). Ordinarily, the midribs and the larger veins are untouched. If forced to it, however, the larvæ will feed on these, or even on the stem, and sometimes also on the flowering parts.

The dock false-worm must not be confused with the true apple sawfly (*Hoplocampa testudinea* Cameron) of England, which has a whitish larva that lives and feeds in young apples, its feeding habits being similar to those of the related American species, the cherry fruit sawfly (*Hoplocampa cookei* Clarke).

CHARACTER OF INJURY TO APPLES.

The dock false-worm is known to injure apples only in the fall, when the fruit is approaching maturity; that is, in September and October. In orchards under observation the larvæ were present on their food plants throughout the growing season, but no evidence of injury was found that had occurred before the apples had practically stopped growing, with one exception. A single Jonathan was found on October 5, into which a larva had succeeded in burrowing some time before the apple had reached maturity. The apple had grown subsequently and had closed the entrance and squeezed the larva to death. The greater hardness of immature apples probably deters the larvæ from burrowing into them. There were no summer apples in the infested orchards, hence it is not known whether these are ever injured.

The injury to apples consists externally of the small round holes bored by the larvæ, which after a few days show a slightly sunken, brownish ring about them and occasionally may be surrounded by a larger discolored halo. (Pl. II, figs. 1 and 2.) These holes may

occur anywhere on the surface, but are most numerous about the calyx and stem ends, or at a point where the apple touches a leaf or another apple, since it is easier for the larva to obtain a foothold here. Within, the injury is usually more serious, since the larva often burrows to the core and usually hollows out a pupal cell somewhat larger than itself. The burrows vary in length from those just started to holes an inch or two deep. It is quite evident that the larvæ are often not entirely satisfied with the apple as a place of hibernation and that they may begin more than one burrow. Apples frequently have three or four, or sometimes even eight, holes in them of varying depths, but contain only one or two worms, or often none at all. In making counts of apples in connection with control work a record was kept on this point, and it was found that in 207 damaged apples there were 364 holes, each apple having from one to eight holes, and that of the 364 burrows only 66, or a little over 18 per cent, had been completed and contained worms.

The burrow is more or less irregular in outline and may be curved or straight. At its end the larva hollows out the slightly larger pupal cell, turns with its head toward the entrance, and forms a plug across the end of the cell, leaving the outer part of the burrow open. This open burrow affords an easy entrance for mold spores, such as those of the blue mold (Penicillium), and the injured fruit frequently starts to rot shortly after being picked, especially if the weather is moist. The larva seems to be well protected against this mold, however, for the fruit tissue immediately surrounding the pupal cell does not rot very readily, but rather becomes dry and pithy. As long as the larva is not actually drowned in the fermenting juices of the rotting fruit it remains alive and healthy. In March, 1915, a number of healthy larvæ were taken from rotten and even mummied Jonathans which had been kept since the preceding September. These larvæ were placed on moist sand, and most of them subsequently pupated and produced adults.

ECONOMIC IMPORTANCE.

Since the dock false-worm does not feed upon any part of the apple tree, but must live upon certain succulent plants, mostly of the buckwheat family, it follows that it can become an apple pest only where these plants are growing in or around the orchard. There can be little or no danger from this insect in clean-cultivated orchards, or in orchards where the food plants do not exist. The possibility of the larvæ coming into the orchard from neighboring meadows, ditch banks, or roadsides is slight, for the larvæ are incapable of finding their way over any extent of bare, cultivated soil. The danger of the larvæ adapting themselves to the apple and feeding upon it is

not to be considered. The apple foliage is so much tougher and dryer than the succulent foliage of the moisture-loving plants upon which they are accustomed to feed that the change of food plants would be practically impossible.

This insect becomes of economic importance, then, only in orchards in which its ordinary food plants are growing, and such orchards would naturally be those that, either through carelessness or because of sod or a cover crop, are not kept clean cultivated. Any orchard kept moist enough to support a cover crop is a favorable place for the food plants of the insect to grow, and since these food plants are widespread, the chances of some one of them, at least, getting into the orchard are very good.

From the description of the injury to apples given above it will be seen that individually this insect is fully as injurious to the fruit as the codling moth, for a single larva will often bore several holes in one apple, and sometimes in several apples, before forming its final burrow. This burrow, too, is often larger than that made by the codling-moth larva and is confined to the flesh of the apple. The tendency of these apples to rot seems to be greater than that of ordinary wormy apples. Collectively, these larvæ have never proved as destructive as many other insects, because they have not been as numerous. It is not inconceivable, however, that they might, under favorable conditions, become a more serious pest.

In the Entiat Valley, Washington, where this insect was chiefly studied, there was a large quantity of wild buckwheat or bindweed (*Polygonum convolvulus*) in the infested orchards, growing in the alfalfa cover crop, and this often was climbing up into the trees for some distance. It can thus be readily seen how the larvæ found their way into the trees and to the fruit. The Jonathan variety was the worst infested, since the tree is of a drooping habit, and the many heavily laden branches, extending down into the alfalfa, afforded the larvæ an easy opportunity to reach the fruit. In the fall of 1914 the extent of injury in one orchard was estimated at about 2 per cent. In 1915 actual counts were made from four representative trees in this orchard, and it was proved that more than 5 per cent of the picked fruit was rendered unmarketable by this worm. This would represent a loss in this particular case of about 16 cents per tree, since the value of the fruit from these trees, which were only 7 or 8 years old, was something over $3 per tree. This was in spite of the fact that the larvæ had been heavily parasitized the preceding spring. The loss may at times be considerably higher, and, in fact, as already noted, Prof. Melander has written of injuries running as high as 10 per cent.

DESCRIPTION.

THE EGG.

The egg of the dock false-worm is bean shaped or kidney shaped, and somewhat flattened, pearly white, and with a soft, pliable shell. It is protected by the tissues of the leaf in which it is deposited, (Pl. I, fig. 1.) The average length is 0.8 mm., and the width 0.6 mm. About a day before hatching a dark spot shows through, which is one of the eyes of the larva, the head being seen from the side. Shortly before the larva breaks through the shell the outline of the head is discernible.

THE LARVA.

The larva would not ordinarily be noticed on the plants until nearly full grown, and it appears at this time as a slender, hairless larva, with a finely wrinkled olive-green or blue-green skin and a scattering of conspicuous white tubercles. After passing the last molt, which brings it to the stage in which it bores into pithy stems or apples, the larva changes in appearance. (Fig. 2.) It is no longer velvety, but has rather a sleek, shiny appearance, though the wrinkles still persist. Its color is a brighter green—more of an apple green—and the larva seems almost translucent, since the alimentary canal is empty. The tubercles are no longer white and can not be distinguished. If an infested stem or apple be cut open, the larva within will be found to have much the same appearance as before it entered, except that it has become shrunken and curved and has lost the power of locomotion. A detailed description of the various larval stages follows:

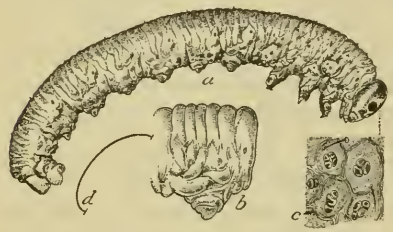


FIG. 2.—The dock false-worm: *a*, Full-grown larva, enlarged; *b*, seventh larval segment, much enlarged; *c*, portion of cranium, highly magnified; *d*, actual length. (Original.)

First instar.—Length, 2.25 mm. General color very light gray; food showing through green. Somewhat slug shaped, thoracic region slightly enlarged, body tapering gradually posteriorly, wrinkled. Head olive brown changing to dark brown, shining; eyes shining black. Just before molting the larva has a shiny, swollen appearance and is somewhat lighter in color.

Second instar.—Length, 4.5 to 5 mm. As before; body wrinkles showing plainly. Head very dark brown, nearly black.

Third instar.—Length, 6 to 8.5 mm. Dorsum greenish gray, merging gradually into the very light yellowish gray of the rest of the body. Body surface wrinkled, dull, numbers of small, sparsely-set setæ being noticeable laterally; surface minutely reticulated, these reticulations being slightly raised and gray dorsally. Head olive brown; mouth parts dark brown; eyes black; thoracic legs same as body, joints marked by dark-brown lines.

Fourth instar.—Length, 9.5 to 14 mm. Dorsum dull bluish green; remainder of body as before. Dorsal surface crossed by whitish lines formed by the wrinkles, and with a scattering of whitish setigerous tubercles. Head light brown, with a dark-brown band dorsally and another crossing the eyes and clypeus. Mouth parts tipped with dark brown.

Fifth instar.—Length, 14 to 17.5 mm.; width of thorax, 2 mm. Body of 13 segments, cylindrical, slightly enlarged in the thoracic region. Integument considerably wrinkled, and with a very finely shagreened surface, which gives the larva a velvety appearance. Dorsal region to the line of the spiracles distinct olive green or occasionally bluish green; ventral region very light yellowish, color changing abruptly at spiracular line.

The dorsal olive-green region appears to be crossed by more or less irregular whitish lines, due to the cuticular folds or wrinkles, and laterally this dark region is even darker, as the raised shagreening is black. The dorsal vessel shows through as a dark-green line. The prothoracic segment is provided with four whitish setigerous tubercles on each side, three of them being in the dark dorso-lateral region and one just above the leg. The other thoracic segments have seven tubercles on each side, having, besides those mentioned above, two near the dorsal line and one latero-ventrally, near the anterior margin of the segment. The abdominal segments, also, have seven tubercles, in slightly different positions, except the last segment, which has only one tubercle on each side of the dorsal line. The anal region is covered with small setæ.

Head narrower than thorax, minutely punctured, sparsely covered with setæ, light brown, a dorsal transverse band of dark brown, incised on the dorsum posteriorly by a triangle of light brown, at each side of which is a distinct, short, longitudinal suture. Dorsal part of clypeus, tips of mandibles, palpi, and antennæ brown. Eyes very dark brown. Abdominal legs, eight pairs, concolorous with venter; thoracic legs, three pairs, the same but somewhat more heavily chitinized, and with the joints marked by brown lines.

Sixth instar.—Length, 14.5 to 16 mm.; width of thorax, 2 mm. (length of parthenogenetic larvæ, 8 to 12 mm.). Similar to fifth-instar larva in shape and skin texture. Color of dorsal region apple green or pale green; ventral region light yellow. Dorsal vessel showing through whitish or yellowish. No dark contents of alimentary canal. The whitish tubercles have disappeared, but the setæ can still be made out in the same positions.

Head covered with small, irregularly rounded, slightly raised, smooth spots, interspersed with raised dots. The spots, when strongly magnified, seem to be made up of two or three cells, this appearance evidently being due to darker markings just beneath the surface. Color of ventral part very light brown, dorsal part, above eye, dark olive brown; clypeus olive brown; tips of mandibles, palpi, and antennæ reddish brown; eyes black.

Prepupal larva.—Length, 6 to 13 mm., average, 10 mm.; male larva smaller than female; cylindrical, somewhat curved dorso-ventrally, shrunken. Body surface wrinkled. Color unchanged.

THE PUPA.

Length, male, 7 to 8 mm.; female, 9 to 11 mm. Elongate, slim, the male smaller than the female and more slender. Sexes distinguished by appearance of tip of abdomen, the female saws being very distinct. Dorsal region apple green. Head, appendages, and ventral and lateral surfaces up to spiracular line, light translucent whitish or yellowish, sometimes with a greenish tinge. Eyes reddish brown.

After a few days the head and thorax become black-brown, and shortly before the adult emerges, the eyes, head, antennæ, thorax, and abdominal plates are jet black, the membrane between the plates being light greenish. The legs are light ferruginous, except the metatarsi, which are black, and the distal tips of the protarsi and mesotarsi, which are dark brown.

THE ADULT.

The adult sawfly (fig. 3; Pl. I, fig. 3) is a slender, blue-black, wasp-like insect, with reddish legs. At first glance it may be mistaken for an ichneumon fly, but it will be distinguished readily by its thicker and heavier abdomen, its relatively shorter antennæ, and in the female by its lack of the usual long, conspicuous ovipositor of the ichneumon fly. The males and females are similar, the males averaging smaller. The description given for *Tuxonus nigrisoma* by Norton (8) characterizes the adult very well, and is given herewith:

Blue black, the legs dark rufous; length 0.30, breadth of wings 0.60 inch. Color blue black; abdomen rather long, flattened, acute; antennæ slender, basal joint enlarged, third longer than fourth; apical joint as long as the preceding; clypeus angulate emarginate; labrum and base of mandibles pale rufous; legs rufous or honey yellow; base of coxæ and tarsi black; wings faintly clouded, stigma and costa black.

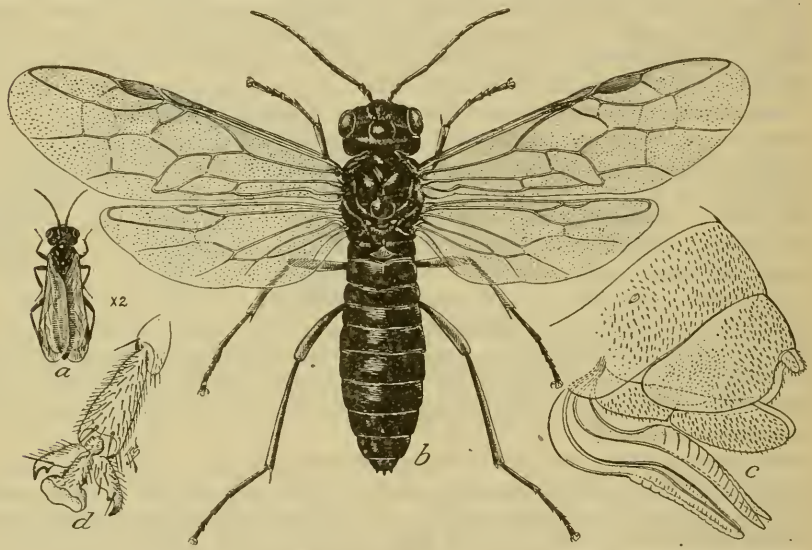


FIG. 3.—The dock false-worm: *a*, Adult fly, twice enlarged; *b*, adult female, much enlarged; *c*, anal segments of female showing ovipositor; *d*, tarsus of hind leg of female. (Original.)

LIFE HISTORY AND HABITS.

METHODS OF STUDY.

In studying the life history of the dock false-worm, rearings were made in an outdoor insectary with a roof but no sides. In order to rear the larvæ under conditions as nearly normal as possible, they were kept on living plants. Small plants of the common curly dock (*Rumex crispus*) and of the wild buckwheat (*Polygonum convolvulus*) were potted in tin cans. After being kept in a cool place for a few days, with plenty of water, these plants appeared normal and made regular growth throughout the season, some of them even producing flowering stalks. The dock plants were by far the most

satisfactory, since they were more easily kept within bounds and their fewer and larger leaves made it easier to locate the larvæ. Oviposition records were obtained by confining freshly emerged adult flies, either pairs or single females, in inverted lantern chimneys placed over these plants and closed at the top by pieces of cheesecloth held in place by rubber bands. A few records, also, were obtained in larger cloth-covered rearing cages. The adults were transferred, usually every day or two, to fresh plants, in order to ascertain more exactly the incubation period of the eggs. These were examined every morning, and the larvæ, as they hatched, were transferred to other plants, or, if not required, were destroyed, because, if left on the same plant, they frequently ate into the unhatched eggs. Several larvæ were ordinarily placed on each plant, since the young ones sometimes fell off and were lost. There was a great regularity in the early molts, making them easy to keep track of, and as the larvæ grew larger they were moved to new plants, only one or two being kept on a plant. The larvæ showed little inclination to wander, and the plants were left uncovered on the shelves. As the larvæ neared the final stage, however, a lantern chimney was inverted over the plant, and several pithy stems, such as those of wild mustard, were placed in the chimney for them to burrow into. However, if the larvæ were discovered just after the last molt, they were transferred to cotton-stoppered glass vials with one of the stems, since they sometimes burrowed into the ground instead of into the stems. Pupation was observed by splitting open the stems a few days after the larvæ had entered. This did not affect them at all, except that during the hot, dry weather they showed a tendency to dry up and die, either before or after pupating. This was avoided by moistening the cotton plugs and by keeping the vials in an improvised moist chamber made of a large lard can. Experiments showed that this did not materially affect the pupal period; indeed, the presence of moisture is undoubtedly a normal condition, since the dead stems in which the larvæ naturally pupate must lie on or near the moist soil in which the food plant is growing. These careful laboratory studies were supplemented by observations in the field, covering chiefly the natural habits of the insect.

NUMBER OF GENERATIONS.

Four generations of the dock false-worm have been distinguished. The generations overlap and become somewhat confused, the reason being apparent when it is noted that the emergence from overwintering larvæ of the spring brood of adult flies in 1915 covered a period of seven weeks, namely, from April 13 to June 4, with a single emergence on June 16. In rearing this insect, it was planned to carry a genealogical series through the season. This attempt was only partially successful, since the hot, dry weather of the latter part of July

cut off the adult emergence of the second generation to a great extent, and, while a number of males were secured, only a single female emerged. The offspring from this female were successfully carried through, however, to four complete generations, the larvæ of the fourth generation, of course, hibernating in their pupal cells and forming spring-brood pupæ and adults the following year. Additional records were obtained by collecting eggs in the field at the time the second-brood adults were emerging and rearing the larvæ from these eggs. It is reasonable to suppose that these eggs were deposited by second-brood adults, since they were collected after July 15, and no spring-brood adults had emerged from the overwintering material after June 16. In selecting adults for oviposition in the insectary, those emerging early and late were, if possible, disregarded, and only those emerging during the period of maximum emergence were used.

Since it was not possible to rear a sufficient quantity of the false-worms to get an adequate idea of the time when each generation occurred in maximum numbers, field observations were made from July 1 to September 8, once a week or oftener. This work was done near the field station at Wenatchee, Wash. As many worms as could be found in a couple of hours were observed, and the instar or stage in each case was recorded. From these figures the percentage of each instar for each date was worked out, thus indicating the broods. Since the infestation was not great enough near Wenatchee to afford a large number of worms for examination at each date, the number running from 20 to 100, the detailed figures are not given here. The diagram in figure 4, however, shows graphically the percentage of full-grown larvæ found on each date. As these figures do not cover the whole season, the lower line is added to the diagram to show the actual number, and not the percentage, of first and second brood larvæ passing the final molt each day, from among those reared at the laboratory. It will be seen that where these two lines overlap they correspond fairly well, and the two together show at a glance when the larvæ of each generation attain maturity. The curves are shown for the mature larvæ, since these are the only ones that ever injure fruit.

HABITS.

Since the habits of the individuals of all generations of the dock false-worm are the same, they will not be considered separately. As we have already indicated, the eggs are deposited in the leaf tissue of the food plants (Pl. I, fig. 1). The larvæ, in escaping, eat a small circular hole through the eggshell and the thin epidermis of the leaf, usually the lower, and crawl out. They begin to feed at once, finding a secure foothold on the rough lower surface of the leaf. At first they eat only through to the upper epidermis, leaving this intact as a thin membrane, but after passing the first molt they begin to eat clear through the leaf, forming irregular holes.

The larvæ molt five times, passing through six stages or instars. During the first and second instars, or until the second molt, the larvæ usually remain on the same leaf. After this they become more or less restless and find their way to other leaves, especially if the first leaf has been supporting several larvæ and is mostly eaten. The younger larvæ lie securely in the hollows they have eaten out of the leaf, clinging to the lower side of the upper epidermis, and they are not easily dislodged. The large larvæ simply lie at full length on the under surface, and if disturbed, curl up the posterior part of the body, holding to the leaf only by the thoracic legs. If the disturbance continues they loosen their hold and drop to the ground, later finding their way back to the leaves. This death feigning, if it may be so called, is a characteristic of this type

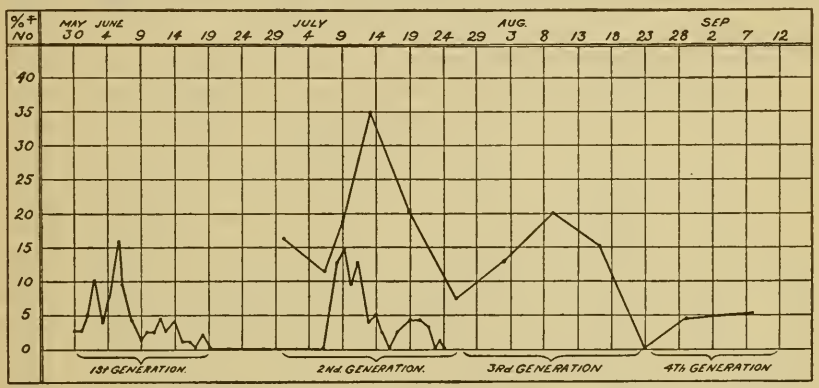


FIG. 4.—The dock false-worm: Diagram showing seasonal abundance of the generations. (Original.)

of sawfly larva, and where the larvæ are numerous a veritable shower of them will be produced by shaking the plants.

The larva ordinarily molts on the leaf where it has been feeding, but sometimes it will migrate to the leaf stem or the base of the plant. It remains quiet for a time before molting, and then the usual peristaltic motion is noticeable. The integument of the head soon splits along the dorsal line to the clypeus, the split forking here and following the clypeal sutures. This frees the head of the larva, which is pushed out, followed by the thorax, and a little time elapses before the mouth parts and thoracic legs are pulled out of their old coverings. Since the posterior part of the old skin is attached to the leaf by means of the hooks on the abdominal legs, the larva is soon able to crawl out, the whole operation occupying six or eight minutes. After molting the larva rests for 10 or 15 minutes in order to allow the new integument to harden somewhat, whereupon it is ready to feed again. The molted integument is not eaten, but remains adhering to the leaf or stem.

No food is taken by the larva after passing the fifth molt and entering the sixth or last instar. The larva usually remains quiet for a time after this molt, as after the others, and then begins to search for a suitable place in which to pupate. This, as a rule, is a dry, pithy stem, such as the flowering stalk of the dock or pigweed, or a dry alfalfa stem. It will also bore into rotten wood or soft bark, if nothing better is available, and, under laboratory conditions at least, will occasionally burrow into the moist earth at the base of the plant. Upon finding a suitable stem the larva at once commences to burrow into it. If the stem has been cut, as may frequently be the case with alfalfa, the larva burrows into the pith at the cut end and soon disappears. Otherwise, it burrows directly into the side of the stem, cutting out a circular hole and then hollowing out the pith within the stem, working the pieces back to the opening with the feet (fig. 1).

The larva burrows an inch or more from the opening and hollows out a pupal cell somewhat larger than itself. When this is accomplished the larva turns around within the cell, returns to the opening, and caps it over with a regurgitated, translucent, mucilaginous substance, mixed with bits of pith. This substance is smeared around the edge of the opening, the mouth parts and fore legs aiding in the process, and the head is moved back and forth until the hole is closed. After this the larva can be seen for a time through the cap, but as the latter is thickened from within the actions of the larva become indistinguishable. The larva then gives its attention to the pupal cell, cleaning it out and often filling up the burrow behind it with pith. A specially compacted mass or plug of pith is formed at the entrance to the pupal cell, as an additional protection, and after completing this the activities of the larva are over, and it soon becomes shrunken and capable of only a slight squirming motion.

The amount of time consumed in making this burrow and forming the pupal cell naturally varies with the condition of the wood, but it usually occupies six or eight hours, unless the larva bores into the cut end of a stem, when the time is considerably shortened. One larva under observation started to bore into the side of a stem at 11.15 a. m., and began to cap the opening at 4.35 p. m. The opening was closed at 5 p. m., and the larva undoubtedly took some time subsequently to complete the burrow. Another larva started its second burrow at noon, after having worked three and a half hours on the first, only to find the stem already occupied, and completed it by 6 p. m. In the breeding cages, where pithy stems were always available for the larvæ, they almost invariably had completed their burrows within 24 hours after the last molt. The larvæ of the summer generations remain in this cell six or eight days before pupating, while the larvæ of the last generation pass the winter here, remaining in the cell six months or more.

In collecting these wintering larvæ in the spring it was observed that when a larva bored into the side of a stem it always formed its pupal cell below the entrance, unless the stem lay in a horizontal position, when it might go either way. In nearly all cases, but not invariably, the head of the larva lies toward the entrance, so that escape may be facilitated. Where the insect is common, more than one larva will frequently be found in one stem, and sometimes as many as four, or five, or even eight. It sometimes happens that a larva in forming its cell pushes the lower plug down too tightly on the larva below, with the result that the latter is killed.

The pupa is able to wriggle about in its cell to some extent but does not force its way out to the entrance when the adult is ready to emerge, as is the case with many wood-boring insects. Several hours before emerging the legs, mandibles, and labrum become somewhat freely movable, with the strengthening of the adult muscles within. After casting the pupal skin the adult sometimes lies in its cell for a day or two, especially if the weather is unfavorable (fig. 1, *b*). It escapes through the original entrance, biting a hole in the cap. If two or more adults are confined in a single vial for several days after emergence they often mutilate each other. sometimes biting off all the appendages.

The adult flies are quite active and take flight readily. They spend their time flying and crawling about over the larval-food plants and the neighboring vegetation, and it is unlikely that they get very far from their birthplace, unless carried by the wind or some other agency. Copulation has not been observed, although numbers of pairs were under observation in breeding jars. No food was observed to be taken, except that the adults occasionally lapped up the little moisture that occurred on the leaves.

The female usually oviposits from the upper side of the leaf, and the egg appears below, very close to the epidermis, in a raised blister about 1.2 mm. long. The ovipositor (fig. 3, *c*, and fig. 5) is thrust into the leaf and gradually worked around to one side by a sawing motion until a nearly circular cell is cut between the upper and lower leaf epidermis. When this is completed, the ovipositor is slowly removed as the egg is deposited. In eight timed ovipositions the operation occupied from 25 to 75 seconds, with an average of 45 seconds. Frequently the eggs are laid in chains, the female after laying one merely moving forward a little and depositing another. Oviposition ordinarily begins within a day after emergence and continues for several days, the majority of eggs, however, being deposited the first two or three days.

PARTHENOGENESIS.

Parthenogenesis—that is, the production of young from unfertilized eggs—has long been known to occur among the sawflies, and the males are ordinarily less common than the females. This partheno-

genesis may take one of several forms. Unfertilized females will deposit eggs which either will not hatch or will hatch and the resulting larvæ will die before attaining maturity, or the larvæ from such eggs will produce only male adults. The dock false-worm belongs to the latter class, the unfertilized females ovipositing normally and the eggs hatching and ultimately producing males.

Great care was taken in rearing the dock false-worm to ascertain the status of parthenogenesis in this species. Single pupæ were kept separate in glass vials, and females emerging from them were confined alone with the larval food plant. They appeared as eager to oviposit as those confined with males, and the average number of eggs deposited

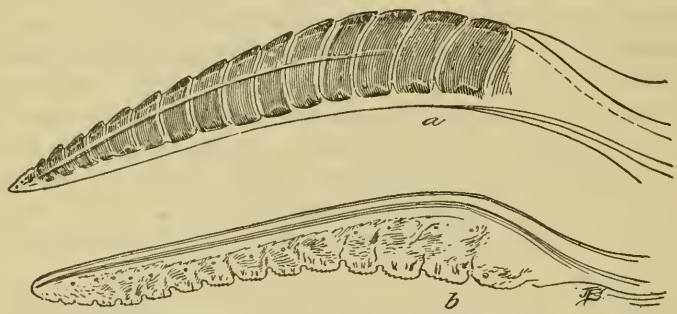


FIG. 5.—The dock false-worm: *a*, Superior saw blade of the ovipositor of adult female; *b*, inferior blade of ovipositor. Highly magnified. (Original.)

by them was greater than that deposited by mated females. The period of development of all stages, as a rule, averaged somewhat shorter than that of normal individuals, comparison, of course, being made only with normal males developing under identical conditions. The figures for parthenogenetic individuals of the various broods are given below, under the heading "Life-history studies," where they are kept separate from the figures for normal individuals. Table I compares the period of development of normal males and parthenogenetic males of the first, second, and fourth generations. No parthenogenetic individuals of the third generation were reared.

TABLE I.—*Comparison of life cycle of normal and parthenogenetic males of the dock false-worm, Wenatchee, Wash., 1915.*

Generation.	Origin of males.	Average number of days in—			
		Egg stage.	Larval stage.	Pupal stage.	Total life cycle.
First	Normal	11.5	33.6	5.5	50.7
	Parthenogenetic	11.2	29.7	5.2	46.1
Second	Normal	6.0	20.9	5.4	32.3
	Parthenogenetic	4.2	20.6	6.3	31.1
Fourth	Normal	4.8	27.8	.....	32.6
	Parthenogenetic	5.8	26.8	.....	32.6

LIFE-HISTORY STUDIES.

The life-history records given below include records of both normal and parthenogenetic individuals. Where both records occur, these are kept separate, since the normal proportion of individuals of parthenogenetic origin in nature is not known. Records of normal males and females are also kept separate in the complete life-cycle tables, except in the table referring to the fourth generation, the individuals of this generation being still in the larval stage at the time of writing.

SPRING BROOD OF PUPÆ AND ADULTS.

Pupal period.—The pupation records of the spring brood of pupæ and the subsequent emergence of the adults were obtained from the overwintering material collected in the Entiat Valley, Wash., on March 17, 1915. Table II gives the length of the pupal period of 40 males and 71 females of the spring brood of pupæ. The average pupal period for males of this brood is 10.2 days, and for the females 10.6 days.

TABLE II.—*Length of pupal period of spring-brood pupæ of the dock false-worm, Wenatchee, Wash., 1915.*

Males.					Females.				
Number of individuals.	Date of—		Days—		Number of individuals.	Date of—		Days—	
	Pupation.	Emergence.	Each.	Total.		Pupation.	Emergence.	Each.	Total.
1	Mar. 31	Apr. 13	13	13	1	Mar. 31	Apr. 14	14	14
1	...do.....	Apr. 14	14	14	2	Apr. 7	Apr. 18	11	22
1	Apr. 5	Apr. 18	13	13	1	Apr. 8	...do.....	10	10
1	Apr. 6	...do.....	12	12	3	Apr. 10	Apr. 19	9	27
1	Apr. 7	...do.....	11	11	1	Apr. 11	...do.....	8	8
2	Apr. 8	Apr. 19	11	22	2	Apr. 12	Apr. 20	8	16
2	Apr. 9	...do.....	10	20	1	...do.....	Apr. 21	9	9
2	Apr. 10	...do.....	9	18	1	Apr. 13	Apr. 22	9	9
3	Apr. 11	...do.....	8	24	7	...do.....	Apr. 23	10	70
1	Apr. 12	...do.....	7	7	1	...do.....	Apr. 24	11	11
4	...do.....	Apr. 21	9	36	5	Apr. 14	Apr. 23	9	45
1	...do.....	Apr. 23	11	11	4	...do.....	Apr. 24	10	40
3	Apr. 13	...do.....	10	30	1	...do.....	Apr. 25	11	11
2	...do.....	Apr. 24	11	22	2	Apr. 15	...do.....	10	20
1	Apr. 14	Apr. 23	9	9	3	Apr. 16	...do.....	9	27
2	...do.....	Apr. 24	10	20	4	...do.....	Apr. 26	10	40
1	...do.....	Apr. 25	11	11	4	Apr. 17	...do.....	9	36
1	Apr. 15	Apr. 26	11	11	7	...do.....	Apr. 27	10	70
2	Apr. 16	...do.....	10	20	1	...do.....	Apr. 28	11	11
3	Apr. 17	Apr. 27	10	30	1	Apr. 18	Apr. 27	9	9
1	...do.....	Apr. 28	11	11	2	...do.....	Apr. 28	10	20
2	Apr. 19	Apr. 29	10	20	3	...do.....	Apr. 29	11	33
1	Apr. 23	May 5	12	12	2	Apr. 19	...do.....	10	20
1	Apr. 24	May 6	12	12	2	...do.....	May 2	13	26
					1	...do.....	May 4	15	15
					1	Apr. 20	...do.....	14	14
					2	Apr. 21	May 5	14	28
					1	Apr. 24	May 6	12	12
					1	Apr. 26	May 8	12	12
					2	Apr. 27	...do.....	11	22
					1	May 4	May 18	14	14
					1	June 9	June 16	7	7
40				411	71				758
Average length in days				10.2	Average length in days				10.6
Maximum				14	Maximum				15
Minimum				7	Minimum				7

Emergence of spring-brood adults.—Table III gives the time of emergence of 201 adult male and female sawflies of the spring brood, including those hibernating both in stems and in apples. The emergence covers a period of over seven weeks, disregarding the single female that emerged on June 16, but the maximum emergence occurred on April 23, only 10 days after the first emergence.

TABLE III.—*Time of emergence of spring-brood adults of the dock false-worm, Wenatchee Wash., 1915.*

Date.	Number of—		Total number.	Date.	Number of—		Total number.
	Males.	Females.			Males.	Females.	
Apr. 13	1	0	1	May 2	1	2	3
Apr. 14	1	1	2	May 4	2	2	4
Apr. 15	1	0	1	May 5	1	5	6
Apr. 16	1	0	1	May 6	1	1	2
Apr. 18	3	3	6	May 7	1	5	6
Apr. 19	14	4	18	May 8	0	3	3
Apr. 20	6	10	16	May 18	0	1	1
Apr. 21	5	1	6	May 19	1	2	3
Apr. 22	4	1	5	May 20	1	0	1
Apr. 23	12	17	29	May 21	0	1	1
Apr. 24	7	6	13	May 24	0	1	1
Apr. 25	2	10	12	May 27	1	1	2
Apr. 26	7	14	21	June 4	0	3	3
Apr. 27	3	11	14	June 16	0	1	1
Apr. 28	2	7	9				
Apr. 29	3	7	10	Total	81	120	201

Length of life of spring-brood adults.—Table IV gives the length of life of 7 males and 11 females confined in lantern chimneys placed over the larval food plant.

TABLE IV.—*Length of life of spring-brood adults of the dock false-worm, Wenatchee, Wash., 1915.*

Males.					Females.				
Number of individuals.	Date—		Days—		Number of individuals.	Date—		Days—	
	Emerged.	Died.	Each.	Total.		Emerged.	Died.	Each.	Total.
1	Apr. 23	May 8	15	15	3	Apr. 23	May 8	15	45
1	...do....	May 9	16	16	3	Apr. 24	May 5	11	33
1	Apr. 24	Apr. 28	4	4	1	Apr. 28	May 8	10	10
2	..do....	May 5	11	22	1	...do....	May 9	11	11
1	Apr. 28	May 8	10	10	1	...do....	May 13	15	15
1	Apr. 29	May 21	22	22	1	...do....	May 15	17	17
					1	May 2	May 14	12	12
7				89	11				143
Average number of days				12.7	Average number of days				13.0
Maximum				22	Maximum				17
Minimum				4	Minimum				10

There is little difference between the length of life of the males and females, the average being 12.8 days, and it is probable that adults in the open would average about the same. Thirty-five adults were confined in the glass vials in which they emerged, with no food or moisture, and these lived an average of only 8.3 days.

Oviposition of spring-brood adults.—Spring-brood adults begin ovipositing within a day of emergence. The maximum period observed was 9 days, with an average of 2.9 days, figuring from date of emergence to date of deposition of each egg. Six mated females of the spring brood deposited an average of 103.6 eggs, the maximum being 117 and the minimum 89; five single females deposited an average of 109.4 eggs, with a maximum of 125 and a minimum of 102.

FIRST GENERATION.

Incubation period of first-brood eggs.—Table V gives the length of the egg stage for 446 fertile eggs and 301 parthenogenetic eggs deposited by spring-brood females in living plants. The fertile eggs of this brood have an average incubation period of 10.7 days, as against 9.9 days for the parthenogenetic eggs.

TABLE V.—*Length of the incubation period of first-brood eggs of the dock false-worm, Wenatchee, Wash., 1915.*

Fertile eggs.					Parthenogenetic eggs.				
Number of eggs.	Date—		Incubation period.	Total days.	Number of eggs.	Date—		Incubation period.	Total days.
	Deposited.	Hatched.				Deposited.	Hatched.		
28	Apr. 25–26	May 7	11.5	332	86	Apr. 29	May 9	10	860
5	do	May 8	12.5	62.5	10	do	May 10	11	110
98	Apr. 25–27	May 7	11	1,078	1	do	May 11	12	12
44	do	May 8	12	528	1	do	May 12	13	13
7	do	May 9	13	91	1	do	May 15	16	16
43	Apr. 28–29	May 8	9.5	408.5	12	Apr. 29–May 5	May 13	11	132
102	do	May 9	10.5	1,071	9	do	May 14	12	108
6	do	May 10	11.5	69	16	May 5–9	May 15	8	128
25	Apr. 29	May 9	10	250	1	do	May 16	9	9
4	do	May 10	11	44	6	do	May 17	10	60
2	do	May 11	12	24	5	do	May 18	11	55
1	do	May 13	14	14	2	do	May 19	12	24
12	Apr. 30–May 5	May 11	8.5	102	12	May 5–8	May 14	7.5	90
8	do	May 12	9.5	76	31	do	May 15	8.5	263.5
50	do	May 13	10.5	525	8	do	May 16	9.5	76
9	do	May 15	12.5	112.5	21	do	May 17	10.5	220.5
1	May 5	May 16	11	11	16	do	May 18	11.5	184
1	do	May 17	12	12	8	do	May 19	12.5	100
					4	May 9	do	10	40
446				4,800.5	3	do	May 21	12	36
Average incubation period				10.7	2	do	May 24	15	30
Maximum				14	38	May 25	June 3	9	342
Minimum				6	5	May 26	June 4	9	45
					3	do	June 5	10	30
					301				2,984
					Average incubation period				9.9
					Maximum				16
					Minimum				6

Length of life of first-brood larvæ by instars.—Seventy larvæ from fertile eggs were reared, at least to the third instar, but of these only 31 were carried to the pupal stage. A partial record was obtained of 19 parthenogenetic larvæ, and a complete record of 8. Table VI gives a summary of the length of larval life by instars, of all larvæ reared.

TABLE VI.—*Summary of larval life of first generation of the dock false-worm by instars, Wenatchee, Wash., 1915.*

Normal larvæ.

First instar.			Second instar.			Third instar.			Fourth instar.			Fifth instar.			Sixth instar.		
Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.
21	4.5	94.5	1	2	2	1	2	2	4	2	8	1	1	1	5	5	25
3	5	15	4	3	12	7	3	21	5	3	15	1	2	2	7	6	42
1	6	6	16	4	64	28	4	112	30	4	120	2	3	6	6	7	42
8	6.5	52	2	4.5	9	20	5	100	18	5	90	4	4	16	3	8	24
11	7	77	21	5	105	6	6	36	3	6	18	12	5	60	5	9	45
2	7.5	15	2	5.5	11	5	7	35	3	7	21	16	6	96	1	11	11
3	8	24	19	6	114	2	8	16	1	8	8	9	7	63	1	12	12
12	8.5	102	2	6.5	13	1	12	12	1	10	10	6	8	48	1	13	13
3	9.5	28.5	2	7	14							1	9	9	1	17	17
1	10	10	1	8	8	70	.....	334	65	.....	290	4	10	40	1	23	23
2	10.5	21				Av.....		4.7	Av.....		4.4	3	11	33			
2	11	22	70	.....	352	Max.....		12	Max.....		10	3	12	36	31	.....	254
			Av.....		5	Min.....		2	Min.....		2				Av.....		8.2
69	.....	467	Max.....		8							62	.....	410	Max.....		23
Av.....		6.7	Min.....		2							Av.....		6.6	Min.....		5
Max.....		11										Max.....		12			
Min.....		4.5										Min.....		1			

Parthenogenetic larvæ.

First instar.			Second instar.			Third instar.			Fourth instar.			Fifth instar.			Sixth instar.		
Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.
1	2.5	2.5	4	3	12	1	3	3	2	2	4	3	1	3	1	5	5
2	4	8	10	4	40	16	4	64	6	3	18	3	2	6	2	7	14
1	5	5	5	5	25	1	5	5	4	4	16	3	3	9	5	8	40
2	6	12				1	6	6	4	5	20	4	5	20			
2	6.5	13	19	.....	77							1	8	8	8	.....	59
2	7	14	Av.....		4	19	.....	78	16	.....	58				Av.....		7.4
6	7.5	45	Max.....		5	Av.....		4	Av.....		3.6	14	.....	46	Max.....		8
*2	8	16	Min.....		3	Max.....		6	Max.....		5	Av.....		3.3	Min.....		5
1	8.5	8.5				Min.....		3	Min.....		2	Max.....		8			
												Min.....		1			
19	.....	124															
Av.....		6.5															
Max.....		8.5															
Min.....		2.5															

Length of life of first-brood pupæ.—Records of the pupal period were obtained from 10 parthenogenetic pupæ, 9 normal male pupæ, and 22 female pupæ, and a summary of these records is given in Table VII.

TABLE VII.—*Summary of pupal stage of first generation of the dock false-worm, Wenatchee, Wash., 1915.*

Parthenogenetic males.			Normal males.			Females.		
Number of individuals.	Days—		Number of individuals.	Days—		Number of individuals.	Days—	
	Each.	Total.		Each.	Total.		Each.	Total.
2	4	8	1	4	4	1	4	4
5	5	25	2	5	10	9	5	45
2	6	12	6	6	36	10	6	60
1	7	7				1	7	7
						1	8	8
10	.....	52	9	.....	50	22	.....	124
Average		5.2	Average		5.5	Average		5.6
Maximum		7	Maximum		6	Maximum		8
Minimum		4	Minimum		4	Minimum		4

Life cycle and emergence of adults of first generation.—Table VIII gives the complete life cycle of 10 parthenogenetic males, 9 normal males, and 22 females. By life cycle is meant the period of growth, or the period from the deposition of the egg to the emergence of the adult. It does not include the length of adult life, during which no growth occurs, nor the interval between emergence of adult and oviposition, these figures being given in a following paragraph.

TABLE VIII.—*Length of life cycle of the first generation of the dock false-worm, Wenatchee, Wash., 1915.*

Parthenogenetic males.								
Individual No.	Date of—				Days in—			Total life cycle in days.
	Egg deposition.	Hatching.	Pupation.	Emergence.	Egg stage.	Larval stage.	Pupal stage.	
1	Apr. 30	May 13	June 15	June 20	13	33	5	51
2	...do.....	...do.....	June 16	June 22	13	34	6	53
3	...do.....	...do.....	June 17	June 23	13	35	6	54
4	May 1	May 14	June 15	June 20	13	32	5	50
5	...do.....	...do.....	...do.....	...do.....	13	32	5	50
6	May 9	May 19	June 14	June 19	10	26	5	41
7	...do.....	...do.....	June 17	June 24	10	29	7	46
8	May 25	June 3	June 30	July 4	9	27	4	40
9	...do.....	...do.....	...do.....	...do.....	9	27	4	40
10	May 26	June 4	June 26	July 1	9	22	5	36
Total					112	297	52	461
Average number of days					11.2	29.7	5.2	46.1
Maximum life cycle, 54 days; minimum, 36 days.								
Normal males.								
1	Apr. 25	May 7	June 10	June 16	12	34	6	52
2	Apr. 27	May 9	June 19	June 24	12	41	5	58
3	...do.....	...do.....	June 21	June 27	12	43	6	61
4	Apr. 30	May 13	June 10	June 16	13	28	6	47
5	...do.....	...do.....	June 11	...do.....	13	29	5	47
6	...do.....	...do.....	June 13	June 17	13	31	4	48
7	...do.....	...do.....	June 16	June 22	13	34	6	53
8	May 8	May 16	...do.....	...do.....	8	31	6	45
9	...do.....	...do.....	June 17	June 23	8	32	6	46
Total					104	303	50	457
Average number of days					11.5	33.6	5.5	50.7
Maximum life cycle, 61 days; minimum, 45 days.								

TABLE VIII.—*Length of life cycle of the first generation of the dock false-worm, Wenatchee, Wash., 1915*—Continued.

Females.								
Individual No.	Date of—				Days in—			Total life cycle in days.
	Egg deposition.	Hatching.	Pupation.	Emergence.	Egg stage.	Larval stage.	Pupal stage.	
1	Apr. 25	May 7	June 8	June 15	12	32	7	51
2	...do....	...do....	...do....	June 16	12	32	8	52
3	...do....	...do....	June 10	...do....	12	34	6	52
4	...do....	...do....	...do....	...do....	12	34	6	52
5	...do....	...do....	June 13	June 18	12	37	5	54
6	...do....	...do....	June 22	June 28	12	46	6	64
7	Apr. 27	May 8	June 12	June 17	11	35	5	51
8	...do....	...do....	June 15	June 20	11	38	5	54
9	Apr. 28	May 9	...do....	June 21	11	37	6	54
10	...do....	...do....	...do....	...do....	11	37	6	54
11	...do....	...do....	June 18	June 23	11	40	5	56
12	...do....	...do....	Jyne 20	June 26	11	42	6	59
13	...do....	...do....	June 24	June 29	11	46	5	62
14	Apr. 30	May 11	June 17	June 23	11	37	6	54
15	...do....	...do....	June 18	June 24	11	38	6	55
16	...do....	...do....	...do....	...do....	11	38	6	55
17	...do....	...do....	June 20	June 25	11	40	5	56
18	...do....	...do....	June 22	June 28	11	42	6	59
19	May 8	May 21	June 18	June 23	13	28	5	46
20	...do....	May 23	...do....	...do....	15	26	5	46
21	...do....	May 24	June 27	July 1	16	34	4	54
22	...do....	May 25	July 1	July 6	17	37	5	59
Total					265	810	124	1199
Average number of days					12.0	36.8	5.6	54.5
Maximum life cycle, 64 days; minimum, 46 days.								
Normal average life cycle					10.7 [1]	35.9	5.6	53.4

[1] Taken from Table V.

The parthenogenetic life cycle averages 46.1 days, the life cycle of normal males, 50.7 days, and the female life cycle, 54.5 days. The average life cycle of normal individuals of both sexes is 53.4 days.

Length of life of first-brood adults.—The warmer weather at the time the first-brood adults are flying appears to reduce the length of their lives, and the average of six adults was 5.3 days, with a minimum of 3 days and a maximum of 7 days.

Oviposition of first-brood adults.—Oviposition begins, in the case of first-brood females, sometimes within a few hours after emergence, and the maximum period observed was 5 days, with an average of 1.7 days. Eggs were secured from six mated females, the average number being 62.3, with a maximum of 92, and a minimum of 39; four single females deposited an average of 67.7 eggs, with a maximum of 90, and a minimum of 46. These females, being reared at the laboratory from eggs deposited there by females of the previous brood, may not have been quite as vigorous as those in nature, which may account for the smaller number of eggs.

SECOND GENERATION.

Incubation period of second-brood eggs.—The length of the second-brood egg stage is shorter than that of the first, owing to the warmer weather at this time, the fertile eggs having an average incubation period of 4.8 days, and the parthenogenetic eggs an average period of 4.3 days. The records for 238 fertile eggs and 202 parthenogenetic eggs are given in Table IX.

TABLE IX.—*Length of the incubation period of second-brood eggs of the dock false-worm, Wenatchee, Wash., 1915.*

Fertile eggs.					Parthenogenetic eggs.				
Number of eggs.	Date—		Incubation period.	Total days.	Number of eggs.	Date—		Incubation period.	Total days.
	Deposited.	Hatched.				Deposited.	Hatched.		
17	June 20	June 26	6	102	29	June 20	June 25	5	145
9	June 21	...do.....	5	45	1	...do.....	June 27	7	7
1	...do.....	June 27	6	6	53	June 21	June 26	5	265
9	June 22	...do.....	5	45	2	...do.....	June 27	6	12
27	...do.....	June 28	6	162	3	...do.....	June 28	7	21
18	...do.....	June 29	7	126	6	June 22	June 27	5	30
7	June 23	...do.....	6	42	14	...do.....	June 28	6	84
14	June 29	July 2	3	42	4	June 23	June 29	6	24
56	...do.....	July 3	4	224	7	June 29	July 2	3	21
3	June 30	...do.....	3	9	64	June 30	July 3	3	192
34	July 3	July 7	4	136	5	...do.....	July 4	4	20
34	...do.....	July 8	5	170	9	July 1	...do.....	3	27
1	...do.....	July 9	6	6	3	...do.....	July 5	4	12
5	July 4	...do.....	5	25	1	...do.....	July 6	5	5
1	...do.....	July 10	6	6	1	July 2	...do.....	4	4
2	...do.....	July 11	7	14					
238				1,160	202				869
Average incubation period..... 4.8 Maximum..... 7 Minimum..... 3					Average incubation period..... 4.3 Maximum..... 7 Minimum..... 3				

Length of life of second-brood larvæ by instars.—Of 43 larvæ which were reared from fertile eggs only 17 reached the pupal stage. The greatest mortality, due to lack of moisture, occurred after the mature larvæ had formed their pupal cells. Forty-seven parthenogenetic larvæ were reared, 6 of them pupating. Table X gives a summary of the length of larval life of all larvæ reared.

TABLE X.—*Summary of larval life of second generation of the dock false-worm, by instars, Wenatchee, Wash., 1915.*

Normal larvæ.																	
First instar.			Second instar.			Third instar.			Fourth instar.			Fifth instar.			Sixth instar.		
Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.
1	1	1	24	1	24	13	1	13	3	1	3	10	3	30	1	5	5
5	2	10	14	2	28	25	2	50	22	2	44	14	4	56	4	6	24
16	3	48	4	3	12	3	3	9	12	3	36	8	5	40	6	7	42
18	4	72	1	4	4	1	4	4	4	4	16	6	6	36	4	9	36
3	5	15				1	6	6	1	5	5	3	7	21	2	10	20
												1	8	8			
43		146	43		68	43		82	42		104	42		191	17		127
Av..... 3.4 Max..... 5 Min..... 1			Av..... 1.6 Max..... 4 Min..... 1			Av..... 1.9 Max..... 6 Min..... 1			Av..... 2.5 Max..... 5 Min..... 1			Av..... 4.5 Max..... 8 Min..... 3			Av..... 7.4 Max..... 10 Min..... 5		
Parthenogenetic larvæ.																	
17	3	51	16	1	16	7	1	7	4	1	4	1	2	2	4	7	28
22	4	88	27	2	54	34	2	68	21	2	42	9	3	27	1	8	8
8	5	40	4	3	12	6	3	18	18	3	54	20	4	80	1	13	13
									3	4	12	6	5	30			
												7	6	42			
												3	7	21			
47		179	47		82	47		93	46		112	46		202	6		49
Av..... 3.8 Max..... 5 Min..... 3			Av..... 1.7 Max..... 3 Min..... 1			Av..... 2 Max..... 3 Min..... 1			Av..... 2.4 Max ..... 4 Min..... 1			Av..... 4.4 Max..... 7 Min..... 2			Av..... 8.1 Max..... 13 Min..... 7		

Length of life of second-brood pupæ.—Pupal records were obtained from 12 normal pupæ, all males, with one exception, and from 3 parthenogenetic pupæ, and a summary of these records is given in Table XI.

TABLE XI.—*Summary of pupal stage of second generation of the dock false-worm, Wenatchee, Wash., 1915.*

Normal individuals.			Parthenogenetic males.		
Number of individuals.	Days—		Number of individuals.	Days—	
	Each.	Total.		Each.	Total.
2	4	8	1	5	5
6	5	30	2	7	14
3	6	18			
1	8	8			
12		64	3		19
Average..... 5.3 Maximum..... 8 Minimum..... 4			Average..... 6.3 Maximum..... 7 Minimum..... 5		

Life cycle and emergence of adults of second generation.—Table XII gives the complete life cycle, from egg deposition to emergence of adult, of 4 parthenogenetic males and 10 normal males of the second generation. The only female of this generation reared to maturity had an abnormal number of molts, and is included elsewhere in this paper.

TABLE XII.—*Length of life cycle of the second generation of the dock false-worm, Wenatchee, Wash., 1915.*

Individual No.	Date of—				Days in—			Total life cycle in days.
	Egg deposition.	Hatching.	Pupation.	Emergence.	Egg stage.	Larval stage.	Pupal stage.	
Pathenogenetic males.								
1	June 21	June 26	July 15	July 22	5	19	7	31
2	...do....	...do....	July 16	July 23	5	20	7	32
3	June 30	July 3	.....	Aug. 1	3	.....	.....	32
4	...do.....	July 4	July 27	...do.....	4	23	5	32
Total					17	62	19	127
Average number of days					4.2	20.6	6.3	31.7
Maximum life cycle, 32 days; minimum, 31 days.								
Normal males.								
1	June 20	June 26	July 16	July 22	6	20	6	32
2	...do.....	...do.....	July 18	July 23	6	22	5	33
3	...do.....	...do.....	July 19	...do.....	6	23	4	33
4	June 22	June 28	July 14	July 20	6	16	6	28
5	...do.....	...do.....	...do.....	July 22	6	16	8	30
6	...do.....	June 29	July 16	...do.....	7	17	6	30
7	...do.....	...do.....	July 17	...do.....	7	18	5	30
8	...do.....	June 28	July 19	July 23	6	21	4	31
9	...do.....	June 29	July 26	July 31	7	27	5	39
10	June 30	July 3	Aug. 1	Aug. 6	3	29	5	37
Total					60	209	54	323
Average number of days					6	20.9	5.4	32.3
Maximum life cycle, 39 days; minimum, 28 days.								

Since the complete rearings of this generation were few in number, the average life cycle of normal individuals has been compiled from the figures in Tables IX, X, and XI, and is given in Table XIII.

TABLE XIII.—*Average life cycle of normal individuals of the second generation of the dock false-worm, Wenatchee, Wash., 1915.*

Number of days in—			Total life cycle in days.
Egg stage.	Larval stage.	Pupal stage.	
4.8	21.3	5.3	31.4

Length of life of second-brood adults.—No records were made of the length of life of second-brood adults.

Oviposition of second-brood adults.—Observations were made on a single pair of second-brood adults. The female deposited 34 eggs the first day after she emerged and 40 eggs the second day, making 74 eggs in all.

THIRD GENERATION.

Incubation period of third-brood eggs.—Seventy-four fertile eggs of this brood hatched in 4 to 6 days after being deposited, with an average incubation period of 4.7 days. No parthenogenetic eggs were secured.

Length of life of third-brood larvæ by instars.—Twenty-nine larvæ were reared from fertile eggs, 9 of them pupating, the remainder either dying or burrowing into the earth at maturity and being lost. No parthenogenetic larvæ were reared. Table XIV gives a summary of the length of larval life by instars of all larvæ reared.

TABLE XIV.—*Summary of larval life of third generation of the dock false-worm, by instars, Wenatchee, Wash., 1915.*

Normal larvæ.																	
First instar.			Second instar.			Third instar.			Fourth instar.			Fifth instar.			Sixth instar.		
Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.
1	1	1	3	1	3	3	1	3	1	1	1	2	2	4	7	4	28
6	2	12	17	2	34	16	2	32	8	2	16	3	3	9	2	5	10
19	3	57	5	3	15	5	3	15	6	3	18	7	4	28			
3	4	12							2	4	8	3	5	15	9	.....	38
			25	.....	52	24	.....	50	1	6	6				Av.....		4.2
29	.....	82	Av.....		2.1	Av.....		2.1				15	.....	56	Max.....		5
Av.....		2.8	Max.....		3	Max.....		3	18	.....	49	Av.....		3.7	Min.....		4
Max.....		4	Min.....		1	Min.....		1	Av.....		2.7	Max.....		5			
Min.....		1							Max.....		6	Min.....		2			
									Min.....		1						

Length of life of third-brood pupæ.—Pupal records were obtained from 9 pupæ of fertile eggs, 4 males and 5 females, and these are given in Table XV.

TABLE XV.—*Summary of pupal stage of third generation of the dock false-worm, Wenatchee, Wash., 1915.*

Number of individuals.	Days.	
	Each.	Total
4	4	16
4	5	20
1	6	6
9	.....	42
Average number of days.....		4.7
Maximum.....		6
Minimum.....		4

Life cycle and emergence of adults of third generation.—Since all but one of the third-brood larvæ reared to the adult stage came from eggs collected in the field, it is not possible to give a complete life cycle of this generation. Table XVI gives a partial life cycle (omitting the egg stage) of 5 males and 5 females.

TABLE XVI.—*Length of partial life cycle of the third generation of the dock false-worm, Wenatchee, Wash., 1915.*

Individual No.	Date of—			Days in—		Total life cycle in days.
	Hatching.	Pupation.	Emergence.	Larval stage.	Pupal stage.	
Males.						
1	July 25	Aug. 12	Aug. 17	18	5	23
2	July 28	Aug. 13	Aug. 18	16	5	21
3	Aug. 1	.....	Aug. 22	.....	.....	21
4	Aug. 17	Sept. 3	Sept. 8	17	5	22
5	...do.....	...do.....	Sept. 9	17	6	23
Total				68	21	110
Average number of days				17	5.2	22
Maximum life cycle, 23 days; minimum, 21 days.						
Females.						
1	July 25	Aug. 12	Aug. 17	18	5	23
2	...do.....	Aug. 13	...do.....	19	4	23
3	July 28	Aug. 14	Aug. 18	17	4	21
4	...do.....	Aug. 15	Aug. 19	18	4	22
5	Aug. 11	Aug. 26	Aug. 30	15	4	19
Total				87	21	108
Average number of days				17.4	4.2	21.6
Maximum life cycle, 23 days; minimum, 19 days.						

As Table XVI is very incomplete, the length of the complete average life cycle has been compiled from separate results obtained for the various stages and is given in Table XVII.

TABLE XVII.—*Average length of complete life cycle of the third generation of the dock false-worm, as compiled from the various stages, Wenatchee, Wash., 1915.*

Number of days in—			Total life cycle in days.
Egg stage.	Larval stage.	Pupal stage.	
4.7	17.6	4.7	27.0

Length of life of third-brood adults.—One male kept with the larval food plant lived 7 days, and two females each lived 5 days.

Oviposition of third-brood adults.—Third-brood females deposited eggs up to 4 days after emerging, the average being 1.9 days, figuring from date of emergence to date of deposition of each egg.

One mated female deposited a total of 133 eggs, and another escaped after depositing 95 eggs. Two single females were observed one of which deposited 83 eggs and the other 104.

FOURTH GENERATION.

Incubation period of fourth-brood eggs.—The length of the fourth-brood egg stage averages a little shorter than that of the second brood, the weather in August being warmer than in June. Records of 174 fertile eggs showed an average incubation period of 3.8 days, and records of 62 parthenogenetic eggs deposited during the same period showed an average of 4.4 days. Table XVIII gives the records for the 174 fertile eggs, and for 157 parthenogenetic eggs, 95 of them being deposited from August 31 to September 4, when the weather was cooler. This makes the total average higher than that of the fertile eggs, as no records of these were secured during this cooler period.

TABLE XVIII.—*Length of the incubation period of fourth-brood eggs of the dock false-worm, Wenatchee, Wash., 1915.*

Fertile eggs.					Parthenogenetic eggs.				
Number of eggs.	Date—		Incubation period.	Total days.	Number of eggs.	Date—		Incubation period.	Total days.
	Deposited.	Hatched.				Deposited.	Hatched.		
1	Aug. 18	Aug. 21	3	3	14	Aug. 20	Aug. 24	4	56
26	...do.....	Aug. 22	4	104	12	...do.....	Aug. 25	5	60
19	...do.....	Aug. 23	5	95	10	Aug. 21	...do.....	4	40
41	Aug. 19	Aug. 22	3	123	11	...do.....	Aug. 26	5	55
28	...do.....	Aug. 23	4	112	8	Aug. 22	...do.....	4	32
6	...do.....	Aug. 24	5	30	6	...do.....	Aug. 27	5	30
1	...do.....	Aug. 25	6	6	1	Aug. 23	...do.....	4	4
25	Aug. 20	Aug. 24	4	100	1	Aug. 31	Sept. 6	6	6
1	...do.....	Aug. 25	5	5	18	...do.....	Sept. 7	7	126
1	...do.....	Aug. 26	6	6	2	...do.....	Sept. 8	8	16
11	Aug. 21	Aug. 24	3	33	2	...do.....	Sept. 9	9	18
11	...do.....	Aug. 25	4	44	10	Sept. 1	Sept. 7	6	60
3	...do.....	Aug. 26	5	15	19	...do.....	Sept. 8	7	133
					1	...do.....	Sept. 9	8	8
					14	Sept. 2	Sept. 8	6	84
					1	Sept. 3	...do.....	5	5
					20	...do.....	Sept. 9	6	120
					3	...do.....	Sept. 10	7	21
					4	Sept. 4	Sept. 11	7	28
174				676	157				902
Average incubation period				3.8	Average incubation period				5.7
Maximum				6	Maximum				9
Minimum				3	Minimum				4

Length of life of fourth-brood larvæ by instars.—As the fourth-brood larvæ do not pupate the same season, but pass the winter in the larval stage, only the period from hatching to the forming of the pupal or hibernating cell by these larvæ is given in the summary in Table XIX.

TABLE XIX.—*Summary of larval life of fourth generation of the dock false-worm, from hatching to forming of pupal cell, Wenatchee, Wash., 1915.*

First instar.			Second instar.			Third instar.			Fourth instar.			Fifth instar.			Sixth instar.		
Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.	Number of individuals.	Number of days each.	Total days.
1	1	1	21	2	42	1	1	1	3	2	6	2	6	12	9	1	9
7	2	14	3	3	9	9	2	18	1	2.5	2.5	2	7	14	2	2	4
13	3	39	2	3.5	7	8	3	24	6	3	18	4	9	36	2	4	8
4	4	16	4	4	16	5	4	20	4	4	16	1	10.5	10.5			
4	5	20	1	4.5	4.5	1	6	6	4	5	20	2	11	22	13	.....	21
4	6	24	1	10	10	1	7	7	1	6	6	1	12	12	Av.....		1.6
3	8	24							1	8	8	1	13	13	Max.....		4
			32	.....	88.5	25	.....	76	1	10	10	1	14	14	Min.....		1
36	.....	138	Av.....		2.7	Av.....		3				1	17	17			
Av.....		3.8	Max.....		10	Max.....		7	21	.....	86.5						
Max.....		8	Min.....		2	Min.....		1	Av.....		4.1	15	.....	150.5			
Min.....		1							Max.....		10	Av.....		10			
									Min.....		2	Max.....		17			
												Min.....		6			

The foregoing table includes individuals from both fertile and parthenogenetic eggs, since there was but little difference between them.

Life cycle of fourth generation.—Table XX gives a partial life cycle of 13 individuals of the fourth generation, including the period from oviposition to the forming of the pupal cell by the full-grown larvæ. This averages 32.6 days for parthenogenetic individuals and 32.7 days for normal individuals. In order to arrive at the complete length of the life cycle of individuals of this generation, we must add to this approximately 200 days, which is the average time spent by the larvæ in the pupal cell, and also 10.5 days, which is the average length of the spring brood (fourth generation) pupal period as shown in Table II. This makes an average total of about 243 days, the complete life cycle of the fourth generation.

TABLE XX.—*Length of partial life cycle of the fourth generation of the dock false-worm, Wenatchee, Wash., 1915.*

Parthenogenetic individuals.						
Individual No.	Date of—			Days in—		Average partial life cycle in days.
	Egg deposition.	Hatching.	Forming pupal cell.	Egg stage.	Larval stage.	
1	Aug. 20	Aug. 24	Sept. 15	4	22	26
2	...do....	...do....	Sept. 16	4	23	27
3	Sept. 1	Sept. 7	Oct. 3	6	26	32
4	...do....	...do....	Oct. 6	6	29	35
5	Sept. 2	Sept. 9	Oct. 10	7	31	38
6	Sept. 3	Sept. 11	Oct. 11	8	30	38
Total				35	161	196
Average number of days				5.8	26.8	32.6

Maximum life cycle, 38 days; minimum, 26 days.

TABLE XX.—*Length of partial life cycle of the fourth generation of the dock false-worm, Wenatchee, Wash., 1915*—Continued.

Normal individuals.						
Individual No.	Date of—			Days in—		Average partial life cycle in days.
	Egg deposition.	Hatching.	Forming pupal cell.	Egg stage.	Larval stage.	
1	Aug. 19	Aug. 23	Sept. 18	4	26	30
2	Aug. 20	Aug. 24	...do....	4	25	29
3	...do....	...do....	Sept. 19	4	26	30
4	...do....	Aug. 26	...do....	6	24	30
5	Aug. 21	...do....	Sept. 22	5	27	32
6	...do....	...do....	Oct. 4	5	39	44
7	...do....	Aug. 27	Sept. 24	6	28	34
Total				34	195	229
Average number of days				4.8	27.8	32.7
Maximum life cycle, 44 days; minimum, 29 days.						

SUMMARY OF LIFE-HISTORY STUDIES.

Table XXI gives a summary of the length of each stage of each generation of the dock false-worm, as worked out at Wenatchee, Wash., in 1915. The column marked "Total life cycle in days" gives the time elapsing between egg deposition and emergence of adult, and the last column gives the time elapsing between the egg deposition of one generation and that of the next. It will be seen that the total of this column (four generations) is 365.6 days, or approximately one year.

TABLE XXI.—*Summary by stages of the length of each generation of normal individuals of the dock false-worm, Wenatchee, Wash., 1915.*

Generation.	Average number of days—				Total life cycle in days.	Average number of days from egg deposition to egg deposition.
	In egg stage.	In larval stage.	In pupal stage.	From emergence to oviposition.		
First	10.7	35.6	5.6	1.7	51.9	53.6
Second	4.8	21.3	5.3	1.5	31.4	32.9
Third	4.7	17.6	4.7	1.9	27.0	28.9
Fourth	3.8	233.0	10.5	2.9	247.3	250.2
Total						365.6

The seasonal history of the dock false-worm is shown in the diagram in figure 6. In order to avoid crowding, only three points in the life history are shown for each generation, namely, the hatching of the eggs, pupation, and the emergence of the adults. Oviposition would come a day or two later than the adult emergence.

ABNORMAL NUMBER OF LARVAL MOLTS.

We have seen that normally the dock false-worm molts five times, and that consequently there are six instars in the larval stage. It seems certain that occasionally, however, there are seven larval

instars. When this was first suspected several larvæ were being reared on a single plant, and while the molted skin was always removed from the leaf when the record of molting was made, there was some doubt as to whether any of the larvæ actually did pass an extra molt. Subsequently, however, the majority of larvæ were reared singly, that is, only one to a plant, and several apparently

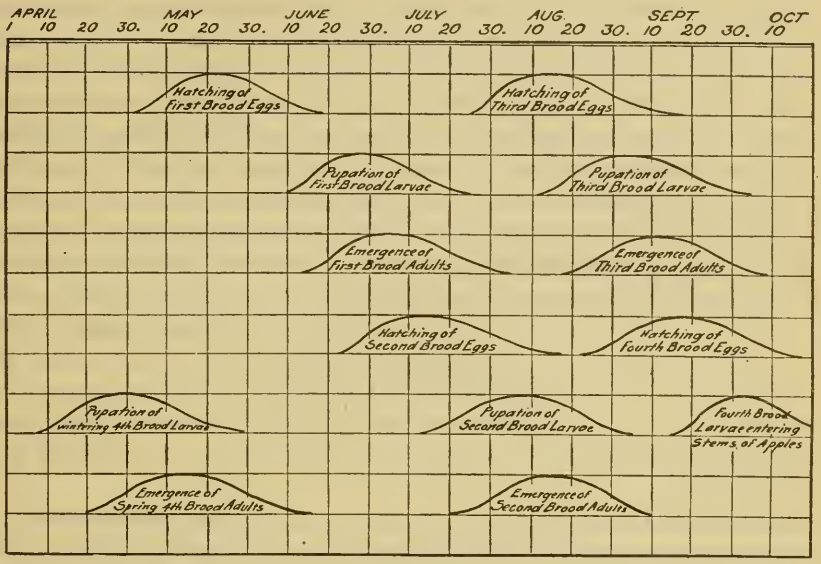


FIG. 6.—The dock false-worm: Diagram illustrating seasonal history. (Original.)

definite records of an extra molt were obtained. These records, while not sufficiently numerous to furnish absolute proof of the occasional occurrence of this additional molt, are given in Table XXII. Individual No. 4 was from an unfertilized egg; the others were from fertile eggs.

TABLE XXII.—*Records of larvæ of the dock false-worm having seven instars, Wenatchee, Wash., 1915.*

Individual No.	Generation.	Date of—									Sex.
		Hatching.	First molt.	Second molt.	Third molt.	Fourth molt.	Fifth molt.	Sixth molt.	Pupation.	Emergence.	
1	1st.	June 29	July 1	July 8	July 11	July 15	July 19	July 26	Aug. 1	.....	♀
2	1st.	July 3	July 5	...do.....	...do.....	July 14	...do.....	July 22	July 29	Aug. 3	♀
3	1st.	...do.....	July 7	July 9	...do.....	July 13	July 17	July 21	.....	.....	..
4	1st.	July 4	...do.....	...do.....	...do.....	July 14	...do.....	July 19	.....	.....	..
5	3d.	July 28	July 31	Aug. 2	Aug. 4	Aug. 10	Aug. 12	Aug. 17	.....	.....	..
6	3d.	Aug. 4	Aug. 7	Aug. 10	Aug. 11	Aug. 15	Aug. 19	Aug. 23	.....	.....	..
7	3d.	...do.....	...do.....	...do.....	Aug. 13	...do.....	...do.....	Aug. 21	.....	.....	..
8	4th	Aug. 26	Aug. 27	Aug. 29	Sept. 1	Sept. 4	Sept. 9	Sept. 21	.....	.....	..
9	4th	...do.....	Aug. 30	Sept. 9	Sept. 16	Sept. 19	Sept. 21	Oct. 3	.....	.....	..
10	4th	Aug. 27	Aug. 29	Aug. 31	Sept. 4	Sept. 10	Sept. 16	Sept. 22	.....	.....	..

RELATION OF TEMPERATURE TO DEVELOPMENT.

Temperature has a very decided influence on the development of insects. Within certain limits increased temperature will hasten development, other factors being equal. The dock false-worm seemed peculiarly susceptible to changes in temperature, and it has already been noted that all stages of its development were shorter in the summer than in the spring. For example, the incubation period of the first-brood eggs (April–May) averaged 10.7 days, while that of the second-brood eggs (June–July) averaged only 4.8 days. Some observations were made on the length of the pupal stage, which, while not taking into consideration the possible effect of differences in humidity and other factors, show very definitely the effect of changes in temperature. The temperature records were obtained from a Richard thermograph placed in the rearing shelter. A sudden rise or fall of temperature hastened or retarded adult emergence. Before April 16 the temperature had only occasionally got above 70° F. From April 16 to 19, inclusive, the daily maximum was above 80° F., and the daily minimum about 50°, whereas it had been about 40° previously. The sawfly pupæ responded to this rise in temperature, and on two days, April 18 and 19, 20 adults emerged from pupæ that had pupated during a period of eight days, or from April 5 to 12, inclusive.

Table XXIII compares the length of the pupal period with the average temperature. This temperature was obtained as follows: The average daily temperature was computed by the sufficiently accurate method of averaging the daily maximum and minimum. Then the average temperature for each individual was obtained by adding the daily averages for the pupal period (including the day of pupation and the day of emergence) of that individual, and dividing by the number of days. The average temperature for a pupal period of any given number of days was then obtained by simply adding the average temperatures of all individuals having a pupal period of that number of days and dividing by the number of individuals. In all, the average temperatures for 137 pupæ of the spring brood and first brood were computed, pupæ from unfertilized eggs not being considered.

TABLE XXIII.—*Length of pupal period of the dock false-worm compared with the average temperature, Wenatchee, Wash., 1915.*

Pupal period in days..	14	13	12	11	10	9	8	7	6	5	4
Average temperature in ° F.....	55.31	55.88	57.65	58.12	58.29	58.62	59.66	61.65	66.60	67.94	70.60
Increase.....	.....	0.57	1.77	0.47	0.17	0.33	1.04	1.99	4.95	1.34	2.66

While no rule can be formulated from the foregoing table, it will be noted that the amount of increase in temperature required to reduce the pupal period one day was greater as the pupal period grew shorter. It required an increase of 3.31° to reduce the pupal period from 14 days to nine days, a reduction of five days, while in order to reduce it from nine days to four days, a further reduction of five days, an increase in temperature of 11.98° was necessary, or over three times as much. The reason for this is evident. It must be remembered that during the pupal stage important changes are taking place. The relatively simple larva is being transformed into the highly complex adult insect. These changes require a certain minimum amount of time, in this case apparently three or four days. On the other hand, there is, at least theoretically, no limit to the maximum amount of time during which the insect may remain in the pupal condition. Hence, as we approach the minimum a greater increase in temperature is necessary in order to produce a given reduction in the length of the pupal period.

NATURAL ENEMIES.

HYMENOPTEROUS PARASITES.

ICHNEUMONIDS.

The overwintering material of the dock false-worm, collected in March, 1915, proved to be rather heavily parasitized. Accordingly a careful record was kept of the parasites, and some knowledge of their life histories was obtained. The parasites emerging were all ichneumonids, and belong to seven distinct species. Mr. R. A. Cushman has examined these and finds them to be *Epiurus pterophorae* Ashm., *Spilocryptus* sp., *Aenoplex* sp., *Bathymetis* sp., *Bathythrix* sp., and two species of Cratocryptus. As only three species were recognized at the time of rearing, and the data obtained were rather meager, they are not presented here. It is certain, moreover, that some of these species are secondary parasites. It is hoped that the opportunity will be presented for further investigations in order to work out this problem.

The adults of all these ichneumonid parasites emerge through a hole bored opposite the pupal cell and not through the entrance hole of the false-worm. They are all more active than the adult sawfly. They are all similar in appearance, and not unlike the adult sawflies, being slender and black, with reddish legs. The antennæ are longer, however, the abdomen more slender, and the ovipositor of the female is conspicuous. The adults of Spilocryptus are further distingushed by a reddish band across the anterior half or two-thirds of the abdomen.

None of these parasites was reared from false-worms that had bored into apples, which indicates that the parasites oviposit in the worms, by means of their stout ovipositors, after the worms have bored into the stems and formed their pupal cells. The parasites would have little opportunity of ovipositing in worms in the apples, even if they could reach them, since the apples are usually picked and hauled away not long after they become infested.

From the infested stems collected in 1915, a total of 261 insects was reared, comprising 92 ichneumonid parasites and 169 sawflies. Thus there was a parasitism of 35.2 per cent.

CHALCIDIDS.

In July and August, 1915, parasitized eggs of the dock false-worm were taken near Wenatchee, Wash. These were black in contrast to the light color of normal eggs. In due time a single small chalcidid emerged from each through a small hole near one end. Specimens submitted to Mr. J. C. Crawford were determined by him to be *Trichogramma minutum* Riley, a minute chalcidid which parasitizes eggs of various Lepidoptera and Hymenoptera, and often practically annihilates its host, at least temporarily. Eggs of the sawfly were collected at intervals from July 26 until September 8, and the amount of parasitism determined. Eggs had been collected several times previous to July 26, but none had been observed to be parasitized. Table XXIV shows the percentage of parasitism.

TABLE XXIV.—*Percentage of parasitism of the eggs of the dock false-worm by Trichogramma minutum, Wenatchee, Wash., 1915.*

Date of observation.	Total number of eggs.	Number parasitized.	Percentage parasitized.
July 26	33	13	39.3
Aug. 2	15	3	20.0
Aug. 16	11	0	0.0
Aug. 23	28	2	7.1
Aug. 30	158	13	8.2
Sept. 8	23	1	4.3
Total	268	32	11.9

BRACONIDS.

Kleine (1908) mentions a parasite of the dock false-worm in Germany, which proved to be *Rhysipolis* sp., a braconid.

PREDACIOUS ENEMIES.

Since the dock false-worm is a soft-bodied larva, living unprotected on the leaves of its food plants, it would be reasonable to suppose that predacious enemies in the form of other insects or birds would prey upon it. Only one such case has been noted, however.

On August 12 a chrysopid (lacewing) larva was discovered in the act of devouring one of the false-worms on a plant at the laboratory. The worm was small, having passed its first molt the day before. On August 26 another chrysopid larva was found eating a worm that had hatched August 24. It is probable that ladybird larvæ sometimes also feed upon immature false-worms.

REMEDIAL MEASURES.

Remedial measures may become necessary for the control of the dock false-worm where its food plants are abundant. Thorough and frequent cultivation will keep the plants from growing in orchards where clean cultivation is practiced. The bindweed (*Polygonum convolvulus*), sometimes called black bindweed, is ordinarily classed as a noxious weed, and the other plants are often troublesome and should be kept out of an orchard, even when the false-worm is not present. However, this is not always possible in orchards kept in sod, or where a perennial cover crop, such as alfalfa, is grown. With this in mind, in the fall of 1915 the writer performed a number of experiments in banding trees and in cleaning out the growth of weeds about them, to determine the best method of preventing the full-grown worms from climbing up and getting at the fruit. This work was done in the orchard from which the overwintering larvæ were collected in the spring. It is situated in the Entiat Valley, 20 miles north of Wenatchee, Wash. A portion of the orchard was selected where there was an average infestation of worms on the bindweed. The latter was growing up into the trees in many places, clinging to the trunks and lower limbs. The orchard consisted of Esopus (Spitzenburg) trees, alternating with Jonathans. Only the latter were used, since the year before it was noted that the Jonathans were injured more than the others. Sixteen trees were used, divided into four plats of four trees each. In Plats A, B, and C, the bindweed and alfalfa were cut off near the ground under the trees, and some of the lowest branches were clipped off, leaving no way for the larva to get into the tree except by way of the trunk. A band of a commercial sticky substance, one-eighth inch thick and 3 inches wide, was then applied to the trunks of the trees in Plat A, just below the point where the main limbs branched out. In Plat B, an 8-inch strip of cotton batting was placed about the trunk of each tree and tied on with cord about the middle. The upper half of the cotton band was then rolled down over the cord. Plat C received no treatment aside from clearing out the weeds and clipping a few branches. Plat D was used as a check and was left untouched. This work was done on August 26, as many of the larvæ were found to be approaching maturity. The fruit was picked October 5, and during the interval other work prevented the writer from visiting

this orchard. The owner found it necessary to prop some of the more heavily loaded limbs, and these props were not banded. Some of the lower limbs, too, became so heavy that they were practically lying on the ground. This prevented the bands from forming an absolute protection against the worms, but there was sufficient protection to make a decided difference. The results of the apple counts made on October 5 are given in Table XXV.

TABLE XXV.—*Number and percentage of apples injured by the dock false-worm in the experimental plats, Entiat, Wash., 1915.*

Condition of fruit.	Plat A (commercial sticky substance).					Plat B (cotton).				
	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Plat.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Plat.
Injured	7	19	7	4	37	0	2	11	4	17
Sound	298	510	628	700	2,136	170	332	466	620	1,588
Total	305	529	635	704	2,173	170	334	477	624	1,605
Per cent injured	2.30	3.59	1.10	0.57	1.70	0.00	0.60	2.30	0.64	1.06

Condition of fruit.	Plat C (weeds cleared).					Plat D (check).				
	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Plat.	Tree 1.	Tree 2.	Tree 3.	Tree 4.	Plat.
Injured	5	23	14	4	46	25	22	38	22	107
Sound	185	535	272	133	1,125	351	531	556	483	1,921
Total	190	558	286	137	1,171	376	553	594	505	2,028
Per cent injured	2.63	4.12	4.90	2.92	3.93	6.65	3.98	6.40	4.36	5.27

This period was almost rainless, and the bands of cotton and commercial sticky substance were in perfect condition on October 5. No difference in effectiveness can be ascribed to the two materials used for bands, the average infestation for the two plats being 1.43 per cent. This is an infestation of only a little over one-fourth that of the check plat. The slightly greater infestation in Plat A (1.70 per cent, as against 1.06 per cent in Plat B) was due to the fact that five props were used in this plat, while only one was used in Plat B, giving the worms more opportunity of reaching the fruit in the former. It was noticed in picking the fruit in these plats that most of the injured apples were on the lower limbs and the limbs that were propped. Practically none were found in the tops of the trees.

The results in Plat C show that merely clearing away the weeds and clipping off the lower branches is of some value, the infestation being about three-fourths that of the check plat. This method may be recommended where banding materials are not at hand.

In general, it may be stated that efficient protection will be secured from the dock false-worm by banding the trees with cotton batting

or other repellent materials safe to the trees, provided the lower limbs are kept well up from the ground and any props used are also banded. The bands should be applied about August 15, and not later than September 1, and under ordinary conditions will remain effective until the fruit is picked. A satisfactory sticky substance may be made by heating 5 pounds of resin until it is melted and then adding 3 pints of castor oil, stirring thoroughly. In using any sticky substance it may be applied directly to the trunks of the larger trees, but if there should be any occasion to use it on trees not more than three or four years old (trees of this age sometimes bear a few apples), a band of paper should first be tightly wrapped about the trunk and the material applied to this, otherwise it may roughen the bark of the tree. Needless to say, this paper band should be removed after the fruit is picked. A band of this substance one-sixteenth inch thick and 3 inches wide is sufficient and will cost about 3 cents a linear foot. The cotton bands are cheaper, costing from 1 to 2 cents a linear foot for bands 6 or 8 inches wide. It takes only a few minutes to apply either material to a tree.

SUMMARY.

The dock false-worm is the larva of a sawfly (*Ametastegia glabrata* Fallén) found all over Europe and in Canada and the northern part of the United States, from the Atlantic to the Pacific.

The larva is a green, wormlike creature, which feeds on dock and related plants; frequently, however, where conditions are favorable, it finds its way at maturity into apple trees, where it bores into the apples to hibernate, making them unsalable.

The dock false-worm has four generations annually, each generation occupying roughly a month, except the fourth, the larvæ of which hibernate and complete their development the following spring. Only the larvæ of this last generation are known to bore into apples.

A number of parasites have been reared, both from the egg and from the full-grown larva, and while these are valuable in partially controlling the false-worm, probably they will never control it absolutely.

Apples may be protected from this insect by keeping the orchard free of dock and other food plants, or, where this is not possible, by banding the trees with cotton or some sticky substance safe to the trees in the latter part of August and leaving the bands on until after the fruit is harvested.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 273

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

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DISPERSION OF GIPSY-MOTH LARVÆ BY THE WIND.[1]

By C. W. Collins,
Entomological Assistant, Gipsy Moth and Brown-tail Moth Investigations.

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INTRODUCTION.

The territory infested by the gipsy moth (*Porthetria dispar* L.) is gradually increasing in area, and since isolated colonies are being found each year in woodlands and orchards remote from lines of travel, the question as to their origin has become more urgent. Many agencies assist in the transportation of the moth in its various stages, but as previous experiments proved that small caterpillars are borne by the wind, it seemed desirable to ascertain to what extent this occurs and the maximum distance they may be blown under field conditions. Much depends upon this factor in diffusion, when devising methods of preventing the spread of this pest, and as a practical result of previous experiments tanglefoot has been used extensively in colonies located in the outside infested towns. Trees are banded with tanglefoot to prevent the small larvæ from ascending to the tops, and thus the chances that these larvæ will be blown long distances are decreased.

[1] An extended report on one of the important phases of gipsy moth control work, conducted under the direction of the Bureau of Entomology, L. O. Howard, Chief, and in cooperation with the various States affected.

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To secure further information, the writer, under the direction of Mr. A. F. Burgess, commenced a series of experiments in the spring of 1913 and continued them throughout the following year.[1]

PREVIOUS INVESTIGATIONS ON DISPERSION OF THE GIPSY MOTH.

Many investigations of various sources of spread of this insect were conducted during the early nineties by Forbush and Fernald and published by the Massachusetts State Board of Agriculture in 1896. It was found that frequent teaming in and out of the original infested areas (Medford, Boston, and towns closely surrounding) by vehicles transporting larvæ that dropped from infested shade and roadside trees was largely responsible for the general local spread during those years. It was also suggested that the larvæ were occasionally transported by the wind to distances of perhaps 100 yards, but no further observations were made at that time to substantiate this theory. Numerous ways and means of local spread, such as by birds, animals, and man, are treated in this valuable report.

In the spring of 1910 Mr. A. F. Burgess began a series of experiments on dispersion of the gipsy moth the account of which is published as Bulletin 119 of the Bureau of Entomology. A few small experiments were made in the laboratory by releasing silk-suspended first-stage gipsy-moth larvæ in front of an electric fan, and it was found that they soared to a distance of 20 to 30 feet in the air before falling. This led to more extensive experiments conducted under out-of-door conditions. Screens constructed of poultry wire and covered with tanglefoot were stationed at given distances from sources of infestation and watched for catches of larvæ. On a small screen stationed on the marshes near Lynn, Mass., newly hatched larvæ were caught that had been carried 1,833 feet by a west wind at a velocity of 7 to 19 miles per hour.

Numerous records were compiled to show the relation of temperature, wind velocity, and wind direction to the general trend of spread as it has progressed from the original center, Medford, Mass. It was clearly demonstrated that the prevalent southwest winds following the hatching period of the eggs each year has resulted in the more rapid dispersion of the moth to the northeast than in any other direction. Large woodland areas were scouted in various towns, the data of which were compiled and show the extent to which the wind is responsible for the remote and numerous colonies located. The automobile is also included in this report, as a very important factor in carrying the caterpillars both locally and for long distances.

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[1] The writer is indebted to Mr. L. H. Worthley and Dr. J. W. Chapman for cooperation and helpful suggestions; to Messrs. C. E. Hood, F. W. Graham, and Harry Blaisdell for the collection of field data; to Mr. H. A. Preston for the preparation of photographic illustrations, and to others of the laboratory force who contributed in various ways.

FORMER INVESTIGATIONS OF HAIRS ON SMALL LARVÆ.

The bodies of first-stage larvæ (Pl. I, fig. 1) are provided both dorsally and laterally with two types of hairs, or setæ, namely, short, smooth hairs bearing a vesicle about the middle and very long, slender ones which are covered with spinules. Wachtl and Kornauth in 1893 first described the aerostatic setæ found on the first-stage larvæ of *P. dispar* L. and *Lymantria monacha* L. and designated the balloon-shaped swellings occurring on these setæ as aerophores. They suggest that these aerophores assist in the dissemination of the young caterpillars through the air.

Prof. Cholodkovsky in 1894 made some investigations and found that the swellings or vesicles shrank in dead larvæ. His discovery tended to weaken the theory that these swellings contain air and to suggest that they may contain a fluid which will naturally dry up after death. He also found that the swellings remained for months in alcohol as full and rounded as in living larvæ, and if the preparation was allowed to dry on a slide the aerophores quickly shriveled. He therefore concluded that they did not contain air but a fluid which was probably poisonous and served as a protection against insectivorous birds.

Igenitzky, a student of Cholodkovsky, in 1897 further studied the glands that give rise to the hairs and verified the findings of the former investigator, who proposed to call the swellings "toxophores." He further states that the rôle of rendering the larvæ more buoyant may better be ascribed to the long thin hairs which resemble the pappus of some plant seeds.

Prof. K. Escherich in 1912 published a résumé of former investigations into the function of the hairs and cites later work by Wachtl and Kornauth in 1907 in which they cling to their former theory of aerophores. The latter found that the vesicles did not contain liquid, as no reaction was noted by immersion in litmus, rosolic acid, or phenolphthalein, indicating that they contained neither alkali nor acid. They did not shrink in alcohol, glycerin, or acetic acid, or excite any capillary action; hence the investigators concluded that nothing but air could be contained in them. Prof. Escherich lays stress on the air refraction noted in connection with these balloons when immersed in glycerin and viewed under the microscope.

T. C. Shcherbakov in 1914 published observations on the gipsy moth in which he deals at length with the function of the hairs on the first and second stage larvæ, and parts of his paper have been translated by Mr. J. Kotinsky of the Bureau of Entomology. Shcherbakov says that the aerophores are not filled with air or gas and that their connection with the glandular cells would indicate that these vesicles are probably filled with a poisonous secretion. Their exceed-

ingly small size, he contends, makes them physically inadequate to sustain the caterpillar in the air. On the other hand, the very numerous, very long hairs which cover the larva, in addition to the wonderful amount of silk it is capable of spinning, point to the general morpho-physiological structure as the factor enabling it to soar.

He compares this ability of the caterpillar with the meaning of soaring as this term is used by V. N. Chitrovo in an epoch-making botanical work on the study of weeds.[1] Soaring is the capability of a body passively to participate in an air current, as if constituting part of it, arising from special characters in the structure of the body. The analogy in function between the wind-borne seed and caterpillar is complete.

Soaring is determined by the coefficient calculated by the following formula:

$$C = \frac{f(\text{cm}^2)}{w(\text{gr})}$$

where C is the soaring coefficient; f, the surface area (in square cm.); and w, the weight (in grams) of the caterpillar. The coefficient of a bare, freshly hatched first-stage caterpillar is 514.285 and Shcherbakov says that it would be more than six times as great if the area of the hairs were included.

Compared with the Chitrovo soaring table of seeds, the coefficient for the first and second stages of the caterpillar places them among the greatest seed soarers. In a slight wind these caterpillars are capable of soaring. The distance they can cover depends on the topography of the country, the character and abundance of vegetation, the mobility of the caterpillar which in turn depends upon the temperature of the atmosphere, and the availability of foods. The soaring coefficient diminishes sharply for caterpillars in the second stage.

This investigator also states that G. G. Jacobson once, while traveling, observed caterpillars flying in masses toward him, despite the fact that he was at least 17 miles away from the nearest forest.

STUDIES OF STRUCTURE AND FUNCTION OF ACUMINATE AND VESICULAR HAIRS.

Owing to the differences of opinion existing as to the structure and function of the hairs covering the bodies of first-stage larvæ, the writer and Mr. C. E. Hood, with the assistance of Dr. J. W. Chapman, made some tests during the winter of 1914–15. The aim of these experiments was to study both the long acuminate hairs and the short ones bearing vesicles. As the results differ somewhat from those of

[1] Atlas von Samen und Früchten der Feldunkräuter aus Mittelrussland. Bul. für angewandte Botanik, wissenschaftliches Organ des Bureau für angewandte Botanik (Monatsschrift), Jahrg. 7, no. 3, 118 p., 16 fig., 13 pl., March, St. Petersburg, 1914.

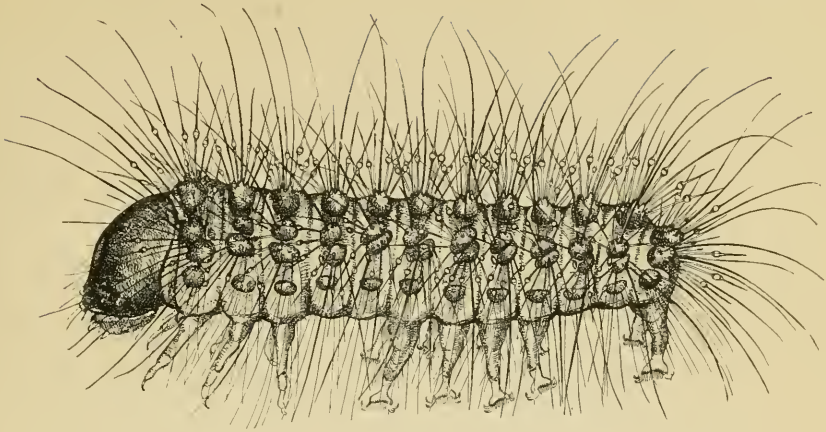


FIG. 1.—FIRST-STAGE LARVA SHOWING TWO KINDS OF HAIRS. (FROM BURGESS.)

FIG. 2.—*a*, TUBERCLE FROM FIRST-STAGE LARVA SHOWING HAIRS; *b*, VESICULAR HAIRS; *c*, ACUMINATE HAIRS. ALL MUCH ENLARGED. (ORIGINAL.)

GIPSY-MOTH CATERPILLAR SHOWING VESICULAR AND ACUMINATE HAIRS.

previous investigators in that the swellings on the short hairs were found to contain a liquid not yet proven to have toxic properties, it seems advisable that they should hereafter be called vesicular hairs. (Pl. I, fig. 2, *b*.) The term "aerophore" previously applied to the swellings on the short hairs is misleading, as is also the term "toxophore" suggested by Cholodkovsky. The term "acuminate" still applies to the very long slender hairs. (Pl. I, fig. 2. *c*.)

After first-stage larvæ die the swellings on the hairs usually collapse and both air and liquid are present in each type of hair and can be seen under a high-power microscope. A living caterpillar examined in glycerin shows air bubbles occasionally in the hairs and swellings which sometimes extend above and below the latter. The air globules and liquid columns alternate in hairs of dead larvæ, and the difference between the air or colorless liquid present is evident from the typical air refractions in the globular form that air always takes in a liquid; also from the capillary attraction of the liquid contained. Living caterpillars mounted in balsam and examined under a microscope show air bubbles in some of the hairs, but such hairs are exceptions rather than the rule. Caterpillars that have been dead several days show the opposite phenomenon—both air and liquid are seen in them, but air predominates. Some larvæ that had been dead for two years were examined and these contained small short columns of liquid, but air filled the greater portion of the hollow spaces of the hairs. Practically the same was noted in the hairs of an exuvium from a first-stage larva which had also been kept about two years. The vesicles on the hairs had buckled or collapsed and contained air, which was later practically all driven out by heating.

Embryos were dissected from the chorion under balsam and glycerin and then examined in these media. No air globules or what could be termed air refractions were noted in either acuminate or vesicular hairs. Many of the vesicles are only partially distended in this stage. Embryos dissected from the chorion in air contained air globules and columns of liquid alternating in a portion of both types of hairs—probably those ruptured during the dissection.

After some experience it is easy with the aid of a high-power miscroscope to recognize the difference in refractions through the walls of hairs full of colorless liquid or containing globules of air and columns of liquid alternating. The typical liquid refractions are always seen in uninjured vesicular and acuminate hairs. Only rarely are there air refractions noted in either type on living larvæ. A decided change in aspect is noted in dead larvæ after the vesicle begins to collapse, at which time air finds its way into the hairs.

A number of living larvæ were placed under a bell jar which contained a small amount of concentrated sulphuric acid. After six hours many of the larvæ were dead and upon examination a large

portion of the vesicles of the hairs had buckled or partly collapsed. Larvæ still living at this time presented the same appearance to a slight extent. As a check on this experiment, larvæ were killed with chloroform and after 24 hours showed a smaller proportion of buckled or collapsed vesicles, indicating that sulphuric acid took up moisture from the porous hairs.

Sections were made of the larvæ and cells at the base of the hairs studied, but there could be found no indication of the presence of glandular cells. A large trichogen, however, is present at the base of each hair. This would signify that the liquid inclosed in the hairs is not a toxin, as Cholodkovsky suggests, but a mere colorless mobile liquid secreted during the formation of the hairs. The phenolphthalein and litmus-solution tests were also tried, with negative results, further indicating a neutral liquid. The peculiar shape of the vesicular hairs, however, suggests that they may at one time have had a poisonous function but that it has been lost in the present generations.

The results of the experiments and observations indicate that both the normal vesicular and acuminate hairs are filled with a colorless liquid; that the hairs are hollow throughout, and that the vesicles contain the same media as the remaining portion of that type. A few globules of air were seen in hairs of living larvæ which were noted as exceptions. Air partially replaces the liquid after death, following which period the vesicles collapse. It is therefore probable, as Igenitzky and Shcherbakov have indicated, that the acuminate hairs play the greater rôle in making the larvæ more buoyant, as these are from four to six times as long as the vesicular hairs.

SCOPE OF INVESTIGATIONS ON WIND DISPERSION.

In that the main purpose of the following investigations was to secure data on the maximum distance and the extent to which small larvæ are borne by the wind, it was necessary to find conditions where an abundance of larvæ were present in close proximity to treeless areas. These conditions were best afforded along the beaches in Massachusetts and New Hampshire, where there are stretches of marshland from 1 to 2½ miles wide and many miles long. These marshlands are occasionally flooded with salt water and do not contain vegetation favorable to the development of gipsy-moth larvæ. The areas selected for the experiments were to the east of the heavy infestations, thereby getting all the advantages previously known to accrue from the northwest, west, and southwest winds. The Isles of Shoals, off the coast of New Hampshire, afforded ideal conditions in so far as their remoteness from the mainland was concerned and the fact that the country opposite has been infested since 1905. Locations were also selected in the hills of New Hampshire near the

quarantine line for experiments intended to explain the sources of many infestations found under such conditions.

Screens of poultry wire, to which tanglefoot was applied, were erected in three of the selected locations along the coast and on the Isles of Shoals (Pl. II). Those used in the New Hampshire hill experiments were of a somewhat different type and are described under that head. The screens used along the coast (Pl. III, fig. 1) were of ¾-inch mesh poultry wire stapled to 2 by 4 posts which were set in the ground and held in place at the top by guy wires and wooden braces. The posts were 12 feet high and two sections of wire each 75 feet long and 3 feet wide were fastened to these so that the top selvage was 12 and the lower 6 feet from the ground. The screens contained 450 square feet of wire and were built in three 25-foot sections, the middle section facing the west and the other two angling from the ends about 45° to the eastward. This gave the greatest exposure at all times to the northwest, west, and southwest winds. A runway was attached to the posts at the bottom selvage of the wire to facilitate examinations.

HATCHING OF EGGS IN RELATION TO WIND DISPERSION OF FIRST-STAGE LARVÆ.

Close observations on the time of hatching of egg clusters in the field have been kept since 1912 by laboratory men stationed in different sections of Massachusetts and New Hampshire. The data consulted were collected by Messrs. E. A. Proctor in northeastern Massachusetts, J. V. Schaffner, jr., in Massachusetts south and southwest of Boston, and I. L. Bailey in south-central New Hampshire.

TABLE I.—*First, maximum, and last dates of hatching in 1912, 1913, and 1914.*

Year.	Northeastern Massachusetts hatching.			Southeastern Massachusetts hatching.			South-central New Hampshire hatching.		
	First.	Maximum.	Last.	First.	Maximum.	Last.	First.	Maximum.	Last.
1912.....	May 2	May 11	May 22	May 1	May 15	May 25	May 1	May 14	May 23
1913.....	Apr. 25	May 5	May 27	Apr. 26	May 10	May 21	Apr. 29	May 8	May 14
1914.....	May 11	May 15	May 28	May 9	May 15	May 23	May 11	May 16	May 28

The first larvæ were caught on the screen in northeastern Massachusetts May 9, 1913, and the last June 5, while the largest numbers were removed between May 14 and June 1. During 1914 in the same section the first larva was caught about May 16, while the largest numbers were removed from May 20 to May 27 and the last June 6. One larva was caught in Henniker, N. H., as late as June 13, 1914.

In a year of normal hatching, as in 1913, wind dispersion was noted about two weeks after first hatching and one week after hatch-

ing was completed. In 1914 there was an abnormally late spring, which shortened the hatching season, and wind dispersion was noted about one week after the first date and continued about the same period after the last was observed. The total period over which windspread may be expected is from 27 to 30 days in a normal spring, and from 18 to 20 days during a late spring. Ordinarily the maximum dispersion is effected during 10 to 15 days of high temperatures and favorable winds.

LONGEVITY OF FIRST-STAGE LARVÆ AFTER BECOMING ENTRAPPED IN TANGLEFOOT.

In connection with the experiments conducted by using tanglefoot on screens to catch caterpillars blown by the wind, it became essential to know about how long they would live after becoming entangled. As a test, tanglefoot was smeared at various depths on heavy paper and 100 caterpillars dropped into these. Examinations were made at intervals from the time the experiment was started, and it was noted that after three hours practically all were living; after six hours only two were attempting to move, and these were in a very thin smear. After eight hours 65 were dead, and 35 showed signs of life when disturbed. The following morning, after 24 hours, all were dead except seven, and these were in very thin smears, which had little effect upon them.

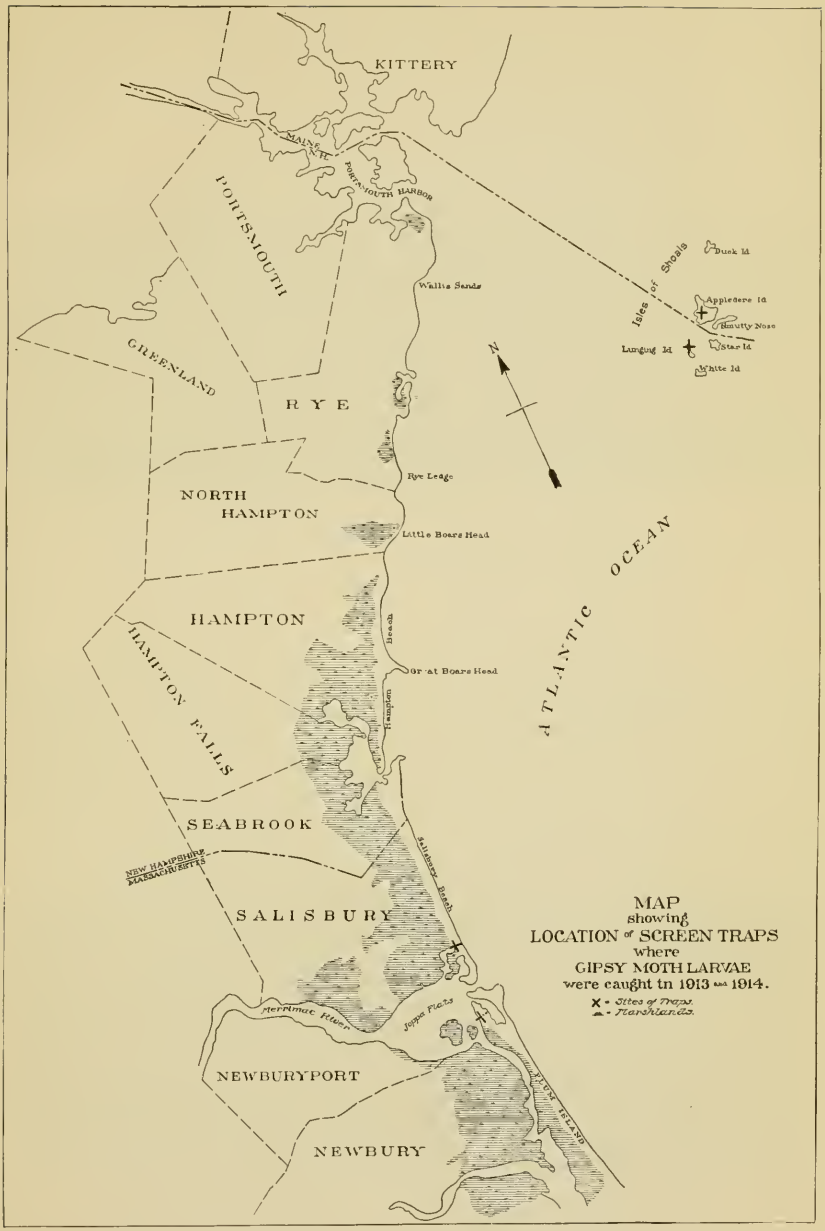
The length of life depended upon the density of the tanglefoot in which they were placed. If the caterpillars in attempting to free themselves became submerged below the spiracles, which often happened in 3 to 5 hours, they died shortly after. As a result, caterpillars lodged in globules of tanglefoot on the screens died in 4 to 6 hours, while those in very thin spots lived 24 or more.

SCREEN EXPERIMENTS AT SALISBURY BEACH, MASS., IN 1913.

April 24, 1913, a large screen (Pl. III, fig. 1), as described, was erected on the edge of the marsh area near the beach, on a site which was 1 mile distant from infested woodlands to the northwest, 1⅛ miles to the west, and 2½ miles to the southwest. The area to the east, composed of sand dunes, contained small amounts of vegetation, on which gipsy moths could thrive, but this was properly scouted and cleaned for an experiment on reinfestation by the wind.

The temperature, wind direction, and wind velocity were taken each day at alternate hours from 9 a. m. to 5 p. m., and the screen was examined most days when the winds were fair for windspread from the west. Mr. F. W. Graham was in attendance at this screen and made many of the following observations and notes.

No larvæ were blown on the screen, which was one-fifth mile from the ocean, by winds coming directly from the east. Larvæ were



MAP SHOWING LOCATION OF SCREEN TRAPS WHERE GIPSY-MOTH LARVÆ WERE CAUGHT IN 1913 AND 1914.

FIG. 1.—SCREEN AT SALISBURY BEACH, MASS., WHERE 266 LARVÆ WERE CAUGHT DURING MAY AND JUNE, 1913, AND 96 IN MAY, 1914. SHOWING BEACH AND OCEAN IN BACKGROUND. (ORIGINAL.)

FIG. 2.—SCREEN AT PLUM ISLAND, MASS., WHERE 42 LARVÆ WERE CAUGHT IN MAY, 1914. NEWBURYPORT IN BACKGROUND 2 MILES WEST—NEAREST INFESTED TREE GROWTH IN THAT DIRECTION. (ORIGINAL.)

SCREEN TRAPS FOR WIND-BLOWN GIPSY-MOTH LARVÆ ON MASSACHUSETTS COAST.

borne, however, by northeast and southeast winds from beach infestations 1 mile or more distant. This screen was inspected in May by Dr. Howard and Dr. Paul Marchal.

TABLE II.—*Dates and numbers of newly hatched caterpillars caught on screen, with temperatures, direction of wind, and velocity of wind, at Salisbury Beach, Mass., in 1913.*

Date and time removed.	Number of caterpillars caught.	Maximum temperature.	Minimum temperature.	Average between 9 a. m. and 5 p. m.	
				Prevailing wind direction.	Wind velocity, in miles per hour.
		°F.	°F.		
May 8	(1)	54	49	S. and SE	11 to 15
May 9, p. m	2	62	52	W. and SW.	8 to 11
May 10	(1)	49	44	NW	18 to 22
May 11, a. m	3	57	50	NW	15 to 18
May 12	(1)	60	56	NW. and SE	8 to 11
May 13	(1)	70	59	SW	10 to 13
May 14, a. m	19	68	62	NW	13 to 17
May 15, a. m. and p. m	71	64	49	W. and SW.	7 to 9
May 16, p. m	15	44	42	NE	8 to 12
May 17, p. m	13	54	50	E. and NE	8 to 12
May 18	(1)	(2)	(2)		
May 19, p. m	25	64	58	W. and NW	18 to 23
May 20, p. m	30	66	55	NW. and W.	15 to 20
May 21, p. m	10	60	51	SE	8 to 12
May 22	(1)	52	48	E. to NW	6 to 8
May 23, p. m	12	58	54	NW., SW., and E.	2 to 5
May 24	(1)	56	52	N. to E	7 to 10
May 25	(1)	53	51	E. and SE	7 to 11
May 26, p. m	16	59	57	NW to E	6 to 10
May 27	(1)	51	48	E	8 to 12
May 28	(1)	48	47	N	8 to 11
May 29	16	64	53	NW	19 to 23
May 30, p. m	3	72	64	W. and NW.	17 to 21
May 31, p. m	11	76	62	NE to NW	8 to 12
June 1, a. m. and p. m	18	77	62	SE to SW	16 to 20
June 2, p. m	0	72	62	NW	16 to 20
June 3, p. m	1	79	72	SW	15 to 19
June 4, p. m	0	62	56	NW. to E	12 to 16
June 5, p. m	1	70	62	E. to S	7 to 11
Total	266				

[1] No examination.

[2] No records.

It will be noted from Table II that 266 caterpillars were caught on 450 square feet of wire, and most of these on days when the winds blew from the northwest, west, or southwest, namely, May 14 to 19, May 15 to 17, May 19 to 25, May 20 to 30, etc., while fewer were caught when the wind was from the northeast and southeast. This may be explained by the light infestations 1 mile or more to the northeast and southeast; also it will be noted that winds from these directions along the coast are accompanied by much lower temperatures, at which time the caterpillars spin less actively.

Many of the small larvæ were taken on the posts and crosspieces of the structure; thus of the 25 caught May 19, 18 had lodged in this manner and were living when removed. Others were swinging by threads on the east side of wire, where they had blown through the mesh from the west, the threads having caught in tanglefoot.

The first larva was caught May 9 and the last June 5, although examinations of later date were made. These dates indicate the range of the wind dispersion period for that section in 1913. The distance borne by the wind was 1 mile or more.

Another small experiment was conducted 200 feet from the above screen by attaching to the northwest, west, and southwest sides of a small stable 77 square feet of cotton cloth which was smeared with tanglefoot. This experiment was not started at the beginning of the season, but 9 larvæ were blown into the tanglefooted cloth between May 20 and 31. The object in this experiment was to ascertain the comparative efficiency of tanglefooted wire screen and a solid tanglefooted surface as traps.

CONTINUATION OF SCREEN EXPERIMENT AT SALISBURY BEACH, MASS., IN 1914.

The same screen (Pl. III, fig. 1) as was erected in 1913 was cleaned and retanglefooted for the dispersion season of 1914. The infestation in the woodlands to the westward, owing to the increase of *Calosoma sycophanta* L., *Compsilura concinnata* Meig., and the wilt disease, was less intense during the latter year. The dispersion period was much later and consequently much shorter than in 1913. Examinations were begun about the time the hatching of eggs was first noted in the field. The first caterpillar was caught May 19 and the last May 31 in this location.

The weather records were taken 1 mile south for this point at Plum Island, Mass. (Pl. II), by Mr. C. E. Hood, and were compared with those of the United States Weather Bureau at Boston, Mass., from which they differed very little.

TABLE III.—*Dates and numbers of newly hatched caterpillars caught on screen, with temperature, direction of wind, and velocity of wind, at Salisbury Beach, Mass., in 1914.*

Date and time removed.	Number of caterpillars caught.	Maximum temperature.	Minimum temperature.	Average between 8 a. m. and 5 p. m.	
				Prevailing wind direction.	Wind velocity, in miles per hour.
		°F.	°F.		
May 19, a. m.	1	78	64	W. and NW.	8 to 12
May 20, a. m.	7	81	66	W. and NW.	2 to 6
May 21, a. m. and p. m.	32	60	53	NE. to SE.	7 to 11
May 22, a. m.	0	60	55	E. and SE.	2 to 10
May 23, a. m. and p. m.	12	78	65	W.	10 to 23
May 24, a. m. and p. m.	14	75	64	W.	11 to 16
May 25, a. m.	7	75	61	SW.	12 to 21
May 26, a. m.	10	89	75	SW. and W.	7 to 20
May 27, a. m.	5	94	79	W. to S.	4 to 12
May 28, a. m.	1	82	75	NW.	11 to 20
May 29, a. m. and p. m.	4	66	56	E. and SE.	9 to 17
May 30, a. m.	2	76	60	SW.	7 to 9
May 31, a. m. and p. m.	1	84	77	W.	7 to 14
Total	96				

In all 96 larvæ were trapped during the season, most of which were removed on days when the wind blew from the west, southwest, or northwest. The largest catch was removed May 21, at which time the wind blew from the northeast and southeast, but it was evident that most of the larvæ were caught May 20 in the afternoon, as the screen was not examined during that period. There was less source of spread from the northeast and southeast along the ocean shore than from the westward points. On May 21 the temperature ranged from 53° to 60° F., at which time there was reasonable activity among the caterpillars.

One should not fail to note that spread was secured from all directions from which the wind blew except from the east, and the infestation at this point was almost obliterated. No north winds were noted during the hourly observation periods.

SCREEN EXPERIMENT CONDUCTED ON PLUM ISLAND, MASS., IN 1914.

April 14, 1914, a screen (Pl. III, fig. 2) was erected on the edge of the marsh near the Merrimac River. It was of the same size and proportions as that erected 1 mile farther north, at Salisbury Beach. The shrubbery, composed mostly of beach plum, bayberry, wild rose, sumac, poplar, and willow, on the north end of the island, was examined for egg clusters and these were creosoted. This practically obliterated the source of infestation to the eastward of the screen.

The location of the screen (Pl. III, fig. 2) was such that it was 2 miles from infested woodlands across the marshes and Merrimac River to the northwest, west, and southwest. Frequent examinations made it possible to determine the direction from which all the caterpillars came. It is not supposed that all the caterpillars caught during the time west winds prevailed came from the nearest infestations (2 miles), but in some instances 5 miles or more. There was, however, a small infestation on a few roadside willows 1 mile to the southwest, but these were so thoroughly cleaned and tanglefooted in the spring that no caterpillars could be found on them during the dispersion season. The woodland infestation was 1 mile beyond this, totaling 2 miles from the screen.

Mr. C. E. Hood attended the screen, making three or four examinations for larvæ daily from May 10 to June 13. The temperature, wind direction, and wind velocity were recorded hourly each day from 8 a. m. to 5 p. m., inclusive.

TABLE IV.—*Dates and numbers of newly hatched caterpillars caught on screen, with temperatures, direction of wind, and velocity of wind at Plum Island, Mass., in 1914.*

Date and time removed.	Number of caterpillars caught.	Maximum temperature.	Minimum temperature.	Average between 9 a. m. and 5 p. m.	
				Prevailing wind direction.	Wind velocity, in miles per hour.
		°F.	°F.		
May 20, a. m. and p. m.	8	81	66	W. and NW.	2 to 6
May 21, a. m.	4	60	53	NE. to SE.	7 to 11
May 22, a. m.	1	60	55	E. and SE.	2 to 10
May 23, a. m. and p. m.	14	78	65	W.	10 to 23
May 24, a. m. and p. m.	7	75	64	W.	11 to 16
May 25, a. m. and p. m.	5	75	61	SW.	12 to 21
May 26, p. m.	1	89	75	SW. and W.	7 to 20
May 27, p. m.	1	94	79	W. to S.	4 to 12
May 28, p. m.	1	82	75	NW.	11 to 20
Total	42				

A total of 42 caterpillars were removed from this trap between May 20 and May 28—a very short season in comparison to the records at Salisbury Beach in 1913. Five of these larvæ were blown on the screen by winds from the east and south, while the remaining 37 came with the winds from the west. Larvæ were caught during the morning of May 20, when the velocity of the wind for that period ranged from 2 to 4 miles per hour, and on the following day, when the temperature ranged from 53° to 60° F.

SCREEN EXPERIMENT ON ISLES OF SHOALS, N. H.

The Isles of Shoals (Pl. II), located 6 miles off the coast of New Hampshire and Maine, was selected as an ideal place in which to establish a trap for tests in long-distance spread. An elevated spot on Appledore Island was chosen and a screen erected in April, 1913. It was not known at that time that Appledore, comprising about 100 acres, was infested, but subsequent scouting in the summer showed that this was the case. This island contains a varied growth of low shrubbery, some of which is very favorable food for gipsy-moth larvæ, but the infestations were slight and covered small areas well scattered over the territory.

The screen was examined at intervals during that year from May 1 to June 3 and 14 first-stage larvæ were removed during that period. Some of these larvæ were alive on removal and were taken on days when the wind blew directly from the mainland, which indicated that many of them came from that source, but there was room for question because the island on which the screen was located in 1913 was later found infested.

To eliminate any possibility of error in drawing conclusions another island in this group, namely, Lunging, was selected for the experiment in 1914. It is the most western of the isles and located so as to

FIG. 1.—SCREEN ON LUNGING ISLAND, ISLES OF SHOALS, N. H., ON WHICH 57 LARVÆ WERE CAUGHT DURING MAY, 1914. OCEAN IN BACKGROUND. VEGETATION IN FOREGROUND IS UNFAVORABLE FOOD FOR THE LARVÆ. (ORIGINAL.)

FIG. 2.—SCREEN ON HOLTS HILL, HENNIKER, N. H., WHERE TWO LARVÆ WERE CAUGHT IN 1914. (ORIGINAL.)

SCREEN TRAPS FOR WIND-BLOWN GIPSY-MOTH LARVÆ IN NEW HAMPSHIRE.

receive the full force of the northwest, west, and southwest winds directly from the mainland. This island is composed mostly of bare rock, with small patches of soil. There is little favorable vegetation for gipsy-moth larvæ, and three careful examinations made in the spring of 1914 revealed no egg clusters.

Four hundred and fifty square feet of wire screen was used, and an extra screen was made of cotton cloth tacked to a frame 40 feet long and 3 feet wide, and tanglefoot applied. It was anchored at an incline on the rocks, facing the west.

On this island there is one cottage which afforded quarters for Mr. Harry L. Blaisdell, who was in constant attendance at the screen (Pl. IV, fig. 1). Arrangements were also made with the United States Life-Saving Service for transportation to and from the islands on their regular trips to Portsmouth, N. H. Mr. Blaisdell recorded the weather conditions hourly from 8 a. m. to 5 p. m., using a compass, thermometer, and hand anemometer. He also examined the screens continuously and made careful notes on the time and wind conditions when each caterpillar was caught, which made it possible to determine the source from which it came. Practically all the larvæ found on the screens were alive, and in most cases they were removed very soon after entanglement.

TABLE V.—*Number of caterpillars caught at Lunging Island, Isles of Shoals, N. H., in 1914, with direction and distance from which they came.*

Date.	Other islands of the Isles of Shoals, E., NE., SE., and S., ½ and ⅝ mile.	Kittery, Me., NW., 7 miles.	Wallis Sands and Rye, N. H., WNW., 6 miles.	Rye Ledge and Little Boars Head, N. H., W., 7 miles.	Seabrook, New Hampshire, and Massachusetts line, WSW., 11 miles.	Plum Island (north end), Mass., SW., 13½ miles.
1914.						
May 20	6	1				
May 21	6					
May 22	1					
May 23			8	3		
May 24			20		1	
May 25	7					9
May 26	2					
May 31	1					
June 1	1					
June 2	1					
Total	25	1	28	3	1	9

Sixty-seven larvæ were removed from the screen and cotton cloth between May 20 and June 2. The wind data given in the table were taken on the island, but comparison was also made with the records taken at Plum Island, Mass., 13½ miles to the southwest. It was thought that the air currents on the shore of the mainland where most of the small larvæ were picked up would be much changed from their course before reaching the islands, but only slight differences were noted by the two observers during the period.

It will be noted, according to the records taken on Lunging Island, that nine larvæ came from the southwest, that is, from Plum Island, 13½ miles away. The weather records at the latter place indicate that conditions were such that at least 18 of those caught on the screen at Lunging Island came from Plum Island, or more distant points in that direction.

Thirteen and one-half miles is the maximum record for distance that larvæ have been carried by the wind in all experiments thus far conducted by us, yet it is probable that the limit has not been reached. The locations for securing such records, together with suitable conditions with reference to infestations, are rare.

DISPERSION EXPERIMENTS ON THE HILLS OF NEW HAMPSHIRE IN 1913 AND 1914.

In the scouting operations conducted by Mr. L. H. Worthley in the outside territory infested by the gipsy moth, numerous infestations were being found on hilltops. It could not be ascertained whether this spread was the result of the wind, vehicles, or other possible carriers—man or animals. These hills contained woodlands, orchards, pastures, mowings, and roads over which there was more or less travel, making spread possible artificially. Thinning was practiced in these infestations, egg clusters were creosoted, and bands of tanglefoot were placed on the trees to keep the first-stage caterpillars hatching near the ground from ascending the trees, thereby decreasing their chances of spread by the wind.

To investigate the source of these hilltop infestations, one hill was selected in each of four towns in New Hampshire, namely, Andover, Henniker (Pl. IV, fig. 2), Hillsboro, and Troy, and large screens erected thereon as traps for the small caterpillars. (See also Plate VII.) It seemed desirable to know if these colonies were the result of windspread, and whether caterpillars were being carried from hilltop to hilltop, valley to hilltop, or vice versa, so that scouting and control methods could be changed accordingly.

The screens were constructed of ⅝-inch mesh poultry wire 3 feet wide. This was stapled to posts set in the form of a T. The posts were about 12 feet high and guyed with No. 13 wire. The wire was fastened in two widths, one above the other, making a screen surface 6 feet wide. The top selvage ranged from 10 to 12 feet from the ground owing to the level of the land. The screens were erected with one wing 35 feet long, facing the north and south, and another, 40 feet long, facing east and west. The total number of square feet exposed to the winds in each screen was 450.

There were known infestations one-third to two miles in all directions from the screens in the foregoing towns, but negative results were

secured on those at Hillsboro and Troy, N. H., the infestations in the neighborhood of which were fewer and at longer distances.

In 1912 several large gipsy-moth colonies were found in Andover and Henniker, N. H. On Beech Hill, Andover, about one-third of a mile from where the screen was erected, over 30,000 larvæ were destroyed in the summer of 1912. This colony and surroundings were carefully treated, so that the infestation was nearly exterminated in 1913 and 1914. All the smaller colonies found in the town also received thorough treatment. Similar conditions prevailed in Henniker.

The screens were examined at periods during the dispersion season of 1913 and 1914. No positive results were secured during the first year, but one living larva was removed from the Andover screen May 27, 1914, at 2 p. m.

May 26, 1914, a dead larva was removed from the Henniker screen and a living specimen June 13, together with the molted skin of a second-stage larva. It is difficult to state from which direction the first larva was blown, but the second came from the northwest or west as the wind blew from those directions during the two days previous.

The 3 first-stage larvæ caught on the Andover and Henniker screens in 1914 proved conclusively that the dispersion among the hills is brought about most extensively by the wind. This is more emphatic when one considers the small air space covered by these traps and the small sources of infestation in these localities.

ALTITUDE EXPERIMENT WITH AVIATION OF SMALL CATERPILLARS.

At the close of the season's work in 1913, after securing some fair records on the distance that larvæ are borne by the wind, it seemed advisable to get data on the possible altitude they reach during their transportation. After numerous inquiries and investigation a suitable place for such an experiment was found in Merrimac, Mass. (Pl. VII). This consisted of the standpipe (Pl. V, fig. 1) for the storage and pressure of the town water. It is located on a small hill 240 feet above sea level, and permission to erect a small wire screen on the top of the tank was obtained from the selectmen of the town.

The tank was 55 feet high from the level of the summit of the hill and a screen of $\frac{3}{4}$-inch mesh poultry wire was stapled to upright 2 by 4 posts 5 feet long. The top selvage of the wire (Pl. V, fig. 2) was 5 feet above the top of the tank, totaling 60 feet above the ground. The screen was 36 feet long and contained 144 square feet, while the tank was 40 feet in diameter, allowing ample space for the examiner to get around the ends. It was set up so that the sides faced the east and west.

Near the tank were a few low trees consisting of white pine and gray birch; these were cleaned of egg clusters and the trunks tanglefooted in order to prevent the larvæ resulting from overlooked egg clusters getting into the tops of the trees. The country about this hill on all sides is generally infested (Pl. VI), so that almost all winds tempered to 50° F. or above bore caterpillars. The weather data used for comparison with the daily catch here was taken at Plum Island, about 10 miles east.

TABLE VI.—*Dates and numbers of caterpillars removed from screen at Merrimac, Mass., in 1914; also general direction of the wind during the period.*

Date and time removed.	Number borne by west winds.	Number borne by east and south winds.	Direction of wind at time of examinations and a few hours previously.
May 19, p. m	[1] 9	0	NW. and W., 8 a. m. to 5 p. m.
May 20, p.m	22	0	NW. and W., May 19, 8 a. m., to May 20, 2 p. m.
May 21	[2]		
May 22, p. m	0	44	NE., E., and SE., May 20, 3 p. m., to May 22, 5 p. m.
May 23, p. m	8	0	W., NW., and SW., May 23, 8 a. m., to May 27, 10 a. m.
May 24, p. m	32	0	Do.
May 25, p. m	2	0	Do.
May 26	[2]		
May 27, p. m	[3] 12	0	Do.
May 27, p. m	0	[3] 6	Changed to S., May 27, 11 a. m., to 5 p. m.
May 28, p. m	2	0	W. and NW., May 28, 8 a. m. to 5 p. m.
May 29	[2]		
May 30, p. m	2	0	SW. and W., May 30, 8 a. m., to June 1, 11 a. m.
May 31	[2]		
June 1, p. m	1	0	S. and SE., June 1, 12 m. to 5 p. m.
June 2, p. m	1	0	W. and NW., June 5, 8 a. m., to June 6, 5. p. m.
Total	91	50	

[1] Some of these larvæ were caught before this date, as 7 were dead on removal.
[2] No examination.
[3] Number accredited to different winds estimated owing to changes in direction.

One hundred and forty-one larvæ were trapped on this screen of 144 square feet between May 19 and June 2, inclusive. A few of these undoubtedly were blown on before May 19, as seven of the nine were dead on removal, indicating that the aviation of the small larvæ began probably two or more days earlier in Merrimac than along the seacoast.

With apparently an equal infestation on all sides of this screen one-half mile or more distant, almost twice as many larvæ were trapped as a result of prevailing winds from the west as from the east.

The data secured in this experiment indicate that all winds during the day in a section generally infested bear caterpillars excepting the north, which was not recorded during this period. Considering that practically one larva was caught per square foot 300 feet above sea level, it is only by conjecture that we can estimate the maximum height reached by them and the length of time they remain suspended under average conditions. It is a known fact that large numbers of

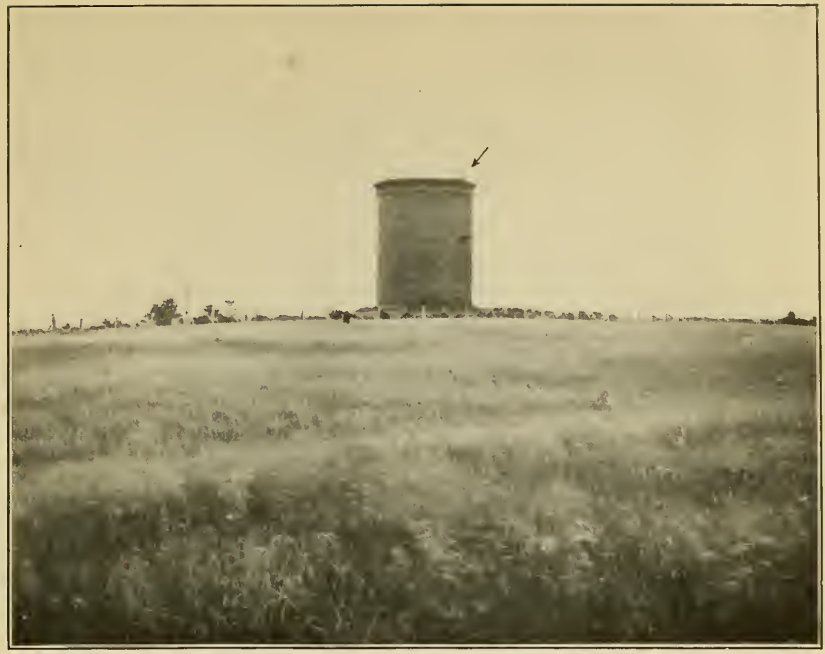


FIG. 1.—SHOWING STANDPIPE, MERRIMAC, MASS. ARROW POINTS TO SCREEN TRAP ON TOP. (ORIGINAL.)

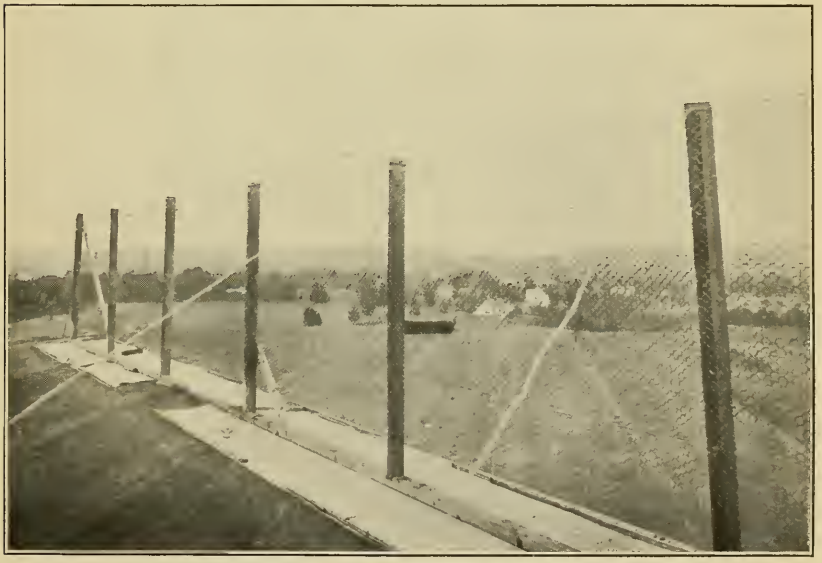


FIG. 2.—SCREEN ON STANDPIPE, MERRIMAC, MASS., AT CLOSE RANGE, WHERE 141 LARVÆ WERE CAUGHT DURING MAY AND JUNE, 1914. (ORIGINAL.)

SCREEN TRAP FOR WIND-BLOWN GIPSY-MOTH LARVÆ, MERRIMAC, MASS.

VIEW FROM TOP OF STANDPIPE, MERRIMAC, MASS., SHOWING SOURCE OF GIPSY-MOTH INFESTATIONS; ALSO YOUNG ORCHARDS WHERE SCATTERING INFESTATIONS WERE LOCATED AS A RESULT OF WIND DISPERSION. (ORIGINAL.)

isolated infestations are scattered in hill and dale over 19,378 square miles of the New England States (Pl. VII), excepting Vermont,[1] and a comparison of such information with the foregoing data at once suggests the source of practically all spread of this species.

OBSERVATIONS ON WIND DISPERSION AT SALISBURY BEACH, MASS., IN 1913 AND 1914.

Salisbury Beach, owing to its separation by extensive marshes from infested woodlands and to the limited amount of favorable food plants for gipsy moths thereon, was selected as a desirable location to be cleaned up and watched for reinfestation. The south end of the beach (Pl. II), $1\frac{1}{8}$ miles in length, was scouted and the egg clusters were creosoted in 1913 and 1914. Beach plum was the predominant shrub growing on the sands and was not fed upon by the caterpillars. Bayberry, wild rose, willow sprouts, balsam poplar, and other small growth thrived to a certain extent and are favored food plants.

The scouting in 1913 resulted in the finding of 144 egg clusters distributed over the beach in a few clumps of shrubbery. The control work was followed up during the summer by frequent examinations for caterpillars, which resulted in their discovery in seven or more places other than where egg clusters were located. From one to six caterpillars were found in small isolated clumps of bayberry and wild rose in no less than six spots near which there were no egg clusters. These patches of favorable food afforded good traps for the newly hatched caterpillars, which were being carried from the infested woodlands 1 mile to the west, as did the tanglefooted screen on which such large numbers were caught the same year.

Seventy-seven egg clusters were found and creosoted in 1914 in the same area as was scouted in 1913. Thus it will be noted that there were slightly more than one-half the number of egg clusters found in 1914 as in 1913, in spite of the rigid control measures practiced during the former year. The location of the beach with respect to the infested woodland across the marshes was ideal for heavy reinfestation each year, and this condition prevails in apple orchards, woodlands, and shade trees that are cleaned within the gipsy moth infested area and become reinfested annually by means of the wind.

OBSERVATIONS ON ISOLATED TREES AND YOUNG APPLE ORCHARDS FOR REINFESTATION.

Twelve isolated trees in the midst of cultivated fields and mowings were selected in the early spring of 1914; these were cleaned of egg clusters, trunks tanglefooted, and later examined for reinfestation by the wind. These trees were selected in towns about Merrimac, Mass.,

[1] During the winter of 1914–15 a few small infestations were discovered in Vermont.

where there was a general infestation. Some of them were later discarded owing to the discovery of overlooked egg clusters that had hatched. On the trees retained there were from 2 to 8 and in one case 11 large caterpillars above and below the tanglefoot, indicating that there was reinfestation by the wind. The top of a medium to large sized apple tree would offer more resistance to the wind than did the screen on the Merrimac standpipe, upon which was lodged approximately one first-stage caterpillar to every square foot of wire exposed.

Some further observations confirming these conclusions were made by Mr. C. E. Hood in July, 1914, in two young apple orchards in Merrimac (Pl. VI) and West Newbury, Mass. These orchards were 2 and 4 years old, respectively, and clean cultivation was practiced in them. A large number of the trees were examined in the center of these orchards, which were in some cases 500 yards from the nearest infestations on larger trees. Thirty-four large larvæ were found in selected areas of the two orchards, not more than one of which appeared on a single tree. No egg clusters could be found, and it was concluded that the infestation was due to windspread.

Mr. J. V. Schaffner, jr., has also reported a similar incident from Dover, Mass.

SMALL LARVÆ BLOWN INTO THE OCEAN ANNUALLY FROM INFESTED WOODLANDS NEAR THE COAST.

At the rate of 266 first-stage larvæ caught on 450 square feet of tanglefooted wire at Salisbury Beach in 1913 (being located 1 mile from the nearest infested woodland), a basis is given for estimating the huge numbers borne into the ocean each year. At the same ratio a continuous screen 1 mile long and 6 feet high would have caught 18,726 larvæ. Judging from the altitude, 300 feet above sea level, where quantities were caught at Merrimac, Mass., it is apparent that this number should be fifty times as much, or 936,300 per mile. There is now upwards of 450 miles of coast line infested in New England (Pl. VII), and figuring that general spread by wind occurs over one-half of this distance, the ocean swallows up annually over 210,000,000 small larvæ. The number is probably much greater than is here indicated, as it is not known how many of the small larvæ passed through the wire meshes of the screen which is used as a basis for these figures.

These calculations, which are partly theoretical, serve to indicate what might have been the result with regard to the area infested had the moth first been introduced 100 miles farther westward than Medford, Mass. It also emphasizes the necessity of keeping this moth confined to New England territory, if rapid and general spread over the United States is to be prevented.

FEEDING OF LARVÆ PRIOR TO DISPERSION BY THE WIND.

Several of the first-stage caterpillars of various sizes caught on the screens during 1913 and 1914 were selected and examined for the presence of plant cells in the alimentary tract. As all caterpillars blown any reasonable distance by the wind are newly hatched, first-stage specimens, it is impossible to ascertain from a superficial examination which have taken food and which have not. Before the examinations were made it was necessary to fix the material, stain with eosin and methylene blue, section with a microtome, and mount on slides, and this work was performed at Bussey Institute, Harvard University, under the direction of Dr. R. W. Glaser of the Bureau of Entomology.

Caterpillars were selected during the two seasons which had been borne by the wind a distance of 1, 2, and 6 or more miles, respectively, from the nearest source of infestation. Results were as follows:

TABLE VII.—*Percentages of small caterpillars having fed which were caught on screens during 1913 and 1914.*

Year.	Locality and distance carried by wind.	Number of caterpillars that had fed.	Number of caterpillars that had not fed.
1913	Salisbury Beach, Mass., 1 mile from infested woodland	13	7
	Isles of Shoals, N. H. Infestation in brushland around screen	1	0
1914	Plum Island, Mass.; 2 miles from infested woodland	2	5
	Isles of Shoals, N. H.; 6 miles or more from infestation on the mainland to the westward	7	8
	Merrimac, Mass.; ½ to 1 mile from heavy infestation in all directions	0	2
	Total	23	22

Of the 45 small caterpillars prepared and examined during the two years that experiments were conducted, 23, or 51 per cent, had consumed a very small amount of food, while the remainder, 40 per cent, showed no signs of it.

COMPARISON OF WEATHER DATA BETWEEN PROVIDENCE, R. I., AND AMHERST, MASS., WITH REFERENCE TO DISPERSION IN 1913.

The period in which first-stage larvæ were borne by the wind in 1913 in eastern Massachusetts was from May 9 to June 5, inclusive. After comparing the hourly wind direction from 7 a. m. to 6 p. m. when there was no rain and the temperature was 50° F. or above at Providence, R. I.,[1] and Amherst, Mass.,[1] one notes a slight difference in the total wind movement in the various directions. For instance, in Providence the wind blew from the northwest 92 hours, from the

[1] The weather records at Providence were secured from the office of the U. S. Weather Bureau, and those at Amherst from the Experiment Station.

north 17, from the northeast 22, from the east 3, from the southeast 51, from the south 37, from the southwest 1, and from the west 9 hours during the foregoing period. In Amherst, Mass., it blew for the same period from the northwest 50 hours, from the north 51, from the northeast 9, from the east 2, from the southeast 30, from the south 31, from the southwest 3, and from the west 46 hours.

Providence was first found infested by the gipsy moth in 1901, and during the scouting season of 1913–14 egg clusters were found as far west as Woodstock, Pomfret, and Brooklyn, Conn.—a distance of 36 miles, or an average spread of 3 miles each year. It is apparent that this general infestation was not accomplished by direct east winds, as there are few recorded each year at the proper period, but by a combination of northeast and southeast winds transporting the larvæ in a southwesterly and northwesterly direction from 1 to 10 miles, thus gaining an average of 3 miles each year directly west.

Although this insect has not yet reached Amherst, Mass., in its general sweep across the country, it occurs within a few miles to the eastward. A perusal of the wind records for the dispersion period of 1913 shows three times as many hours of north winds and about one-half as many northeast and southeast winds combined as are recorded in Providence, R. I. The total movement of northwest and west winds, which blow the larvæ back into the infested territory each year, is practically the same in the two localities.

From this data it appears that the increase in the amount of north winds and the decrease in combined northeast and southeast winds at Amherst, when compared with the wind records at Providence, may result in a somewhat more rapid southwestern advance of the insect if it becomes established in the Connecticut Valley. More rapid southern and western spread is likely if the infestation reaches the Central States.

SPREAD OF THE GIPSY MOTH IN NEW ENGLAND.

The gipsy moth was introduced at Medford, Mass. (Pl. VII), in 1869, from which point it has spread gradually over large areas in Massachusetts and other New England States, excepting Vermont.[1] Small infestations have also been located in New York, New Jersey, and Ohio, but these colonies are fast being exterminated. Extensive efforts to prevent spread have been carried on in Massachusetts by the State since 1890, with suspension of appropriations and efforts only from 1900 to 1905. Other infested States have appropriated smaller amounts which have aided in the suppression work. Congress began making appropriations in 1906, and these annual sums have been expended to prevent spread and help control of the gipsy moth and the brown-tail moth.

[1] See, however, footnote on p. 17.

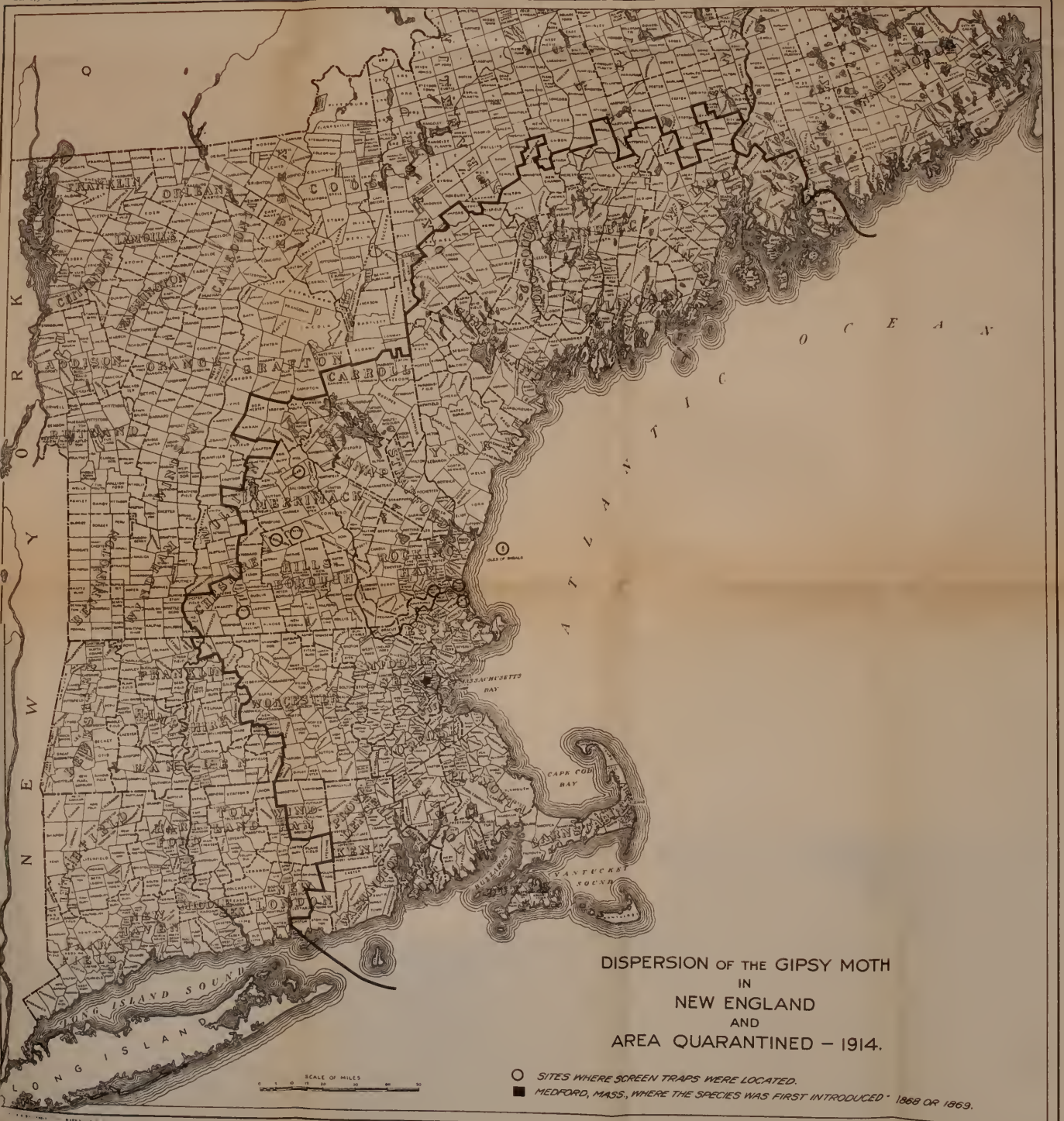

DISPERSION OF THE GIPSY MOTH
IN
NEW ENGLAND
AND
AREA QUARANTINED — 1914.
SITES WHERE SCREEN TRAPS WERE LOCATED.
MEDFORD, MASS., WHERE THE SPECIES WAS FIRST INTRODUCED · 1868 OR 1869.
SCALE OF MILES
ATLANTIC OCEAN
NEW YORK
LONG ISLAND
LONG ISLAND SOUND
MASSACHUSETTS BAY
CAPE COD BAY
NANTUCKET SOUND
VINEYARD SOUND
BUZZARDS BAY
FRANKLIN
HAMPDEN
HAMPSHIRE
WORCESTER
MIDDLESEX
ESSEX
NORFOLK
BRISTOL
PLYMOUTH
BARNSTABLE
DUKES
NANTUCKET
BERKSHIRE
FRANKLIN
HAMPDEN
HAMPSHIRE
WORCESTER
MIDDLESEX
ESSEX
NORFOLK
BRISTOL
PLYMOUTH
BARNSTABLE
DUKES
NANTUCKET

Table VIII is here presented to show the annual advance of the moth before and after control was attempted. This indicates that the winds are chiefly responsible for the present conditions.

TABLE VIII.—*Spread of the gipsy moth in various directions by series of years from five years after its introduction at Medford, Mass., to 1914.*

Periods of years.	NE.	N.	NW.	W.	SW.	S.	SE.	Average spread per year by periods.
	Miles.	*Miles.*	*Miles.*	*Miles.*	*Miles.*	*Miles.*	*Miles.*	*Miles per year.*
1875–1890	15	10	5	10	6	4	3	0.5
1891–1899	5	4	5	4	4	5	4	.5
1900–1905	27	11	12	10	12	14	62	3.5
1906–1909	41	60	25	19	15	16	11	6.7
1910–1914	114	16	28	15	24	26	0	6.4
Total	202	101	75	58	61	65	80	
Average for 40 years								2.3
Average spread per year in various directions	5	2.5	1.9	1.5	1.5	1.6	2	

It will be noted that the spread from the original center was very slow, averaging only 0.5 of a mile per year up to the beginning of the campaign in 1890. It was then held in control for a period of about nine years, during which time there was very little advance into new territory. The conditions in the old infested area were also much improved. This shows the necessity for keeping the moth under complete control if windspread is to be prevented. During the period from 1900 to 1905, when no work was being done, the moths spread at the rate of 3.5 miles per year. This had increased to 6.7 miles per year from 1906 to 1909, but this ratio has decreased to some extent in the last period up to 1914, inclusive.

The greatest distance gained in various directions has been to the northeast, an average of 5 miles per year for 40 years, which is the result of the favorable southwest winds. The combination of southeast and southwest winds during the dispersion period has carried the larvæ northward at the rate of 2.5 miles per year. The spread to the west, southwest, and south was accomplished at a slower rate, owing to the less favorable winds blowing in those directions.

SUMMARY.

In 1913, as a result of the several experiments conducted by using tanglefooted screens and cloth for traps, there were caught on 977 square feet 289 first-stage larvæ which had been borne by the wind one-eighth to 1 mile or more. In 1914 there were removed from 1,614 square feet of sticky surface 346 larvæ which had been blown from one-eighth to 13½ miles or more, as verified by the wind records taken at or near those points. Three larvæ were also taken from two large screens on the hills in New Hampshire during 1914.

Considering the great numbers of larvæ taken in these experiments, there can be no doubt that the wind is almost wholly responsible for the general spread of this insect in New England, notwithstanding the fact that many of the former publications teem with explanations of possible accidental or artificial spread by man and animals. The recent establishment by the Federal Horticultural Board of a quarantine on lumber products, Christmas trees, nursery stock, and stone moving from the infested territory, until inspection has been made, has greatly relieved the danger of a general distribution of the gipsy and brown-tail moths over the United States, but the sources of dispersion of the gipsy moth by the wind can only be lessened by the effectiveness of the parasites and predaceous enemies, together with hand methods of control. To prevent continual spread by the wind into new territory the badly infested areas near the border must be brought under control either by natural enemies, or hand methods, or both. Natural enemies, however, are now playing an important rôle in the control of this insect in the greater area of the inside infested territory.

The larvæ are sufficiently active and allow themselves to be transported by the wind at temperatures of 55° F. and above, and have been caught at wind velocities varying from 2 to 23 miles per hour, although more active spread takes place when the temperature ranges from 65° to 85° F. and when the velocity reaches 8 miles or more per hour. Larvæ are removed from their support and carried by sudden gusts of wind, whether they spin or not, when the temperature reaches 50° to 55° F., at which temperatures they often start crawling.

The records also show that larvæ have been caught at times when winds were blowing from all directions except the north—only a very few coming from the east, but the location of the screens along and near the coast materially affected this condition. By far the larger numbers were borne by combinations of the west winds as indicated on the screen at Merrimac, Mass., which was surrounded by a general infestation.

The general progress of the species since its establishment at Medford, Mass., at the rate of 5 miles per year to the northeast and at the rate of 3 miles per year westward from Providence, R. I., since its first appearance there in 1901 tends to verify the data that have been collected in connection with the screen experiments.

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V. INSECTS.

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 276

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER September 29, 1915

THE PEA APHIS WITH RELATION TO FORAGE CROPS

By

J. J. DAVIS, Entomological Assistant, Cereal and Forage Insect Investigations

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CORRECTION.

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On page 54 the legend to figure 17 should read as follows:

"Fig. 17.—Larva of the cecidomyiid fly Aphidoletes sp., which preys upon Macrosiphum pisi. Enlarged. (Original.)"

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INTRODUCTION.

The periodic occurrence of the pea aphis (*Macrosiphum pisi* Kalt.) in unusual abundance on various leguminous crops, more especially red and crimson clovers, vetches, field and garden peas, and sweet peas, has placed it among the important injurious insects of the world, for it is almost cosmopolitan and more or less injurious wherever found. In Europe it has been the subject of numerous treatises, both from the systematic and economic viewpoints, and its identity has been much confused with other closely related species. In America it seems to have made its first appearance in destructive and noticeable numbers in 1899, although it is known to have been present here for at least two decades previous, and each year since 1899 this aphis has been recorded as injurious in one or more localities in the United States.

In the present paper we have attempted especially to settle the identity of the species, an important item from the economic standpoint, and to report our extended life-history investigations, together with a summary of all the important facts, both old and new, relative to the life economy of the species.

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SYNONYMY.

This aphis seems to have been first authentically described under the name *Aphis pisi* by Kaltenbach in 1843 (5),[1] although two years previous Boyer de Fonscolombe (3) described a species under the name *Aphis onobrychis*, which is still doubtfully considered synonymous with *pisi* as will be noted later. Kaltenbach placed Schrank's *Aphis ulmariae* as a synonym of *pisi*, although this arrangement on the part of that author is not comprehensible, since he was doubtless aware of its priority over *pisi*. In 1855 Koch (6) redescribed *pisi* and placed it in the genus Siphonophora, no mention being made of *ulmariae*, although in the appendix of this work (p. 328) Kaltenbach's remarks include the following:

Siph. gei Koch ist, nach Herrich-Schäffer's richtiger Vermuthung, meine *Aphis Pisi* Kalt. und *Aph. Onobrychis* B. de Fonsc. Der ältere Schrank'sche Name *Aph. Ulmariæ* verlangt jedoch von allen Dreien das Prioritätsrecht.

The name *pisi* was adopted by entomologists almost universally until comparatively recent years when *ulmariae* was more or less generally accepted.

In 1909 Dr. N. A. Cholodkovsky (9) published the results of his studies on *Siphonophora pisi* and related species, definitely settling the identity of *pisi*, and for the first time pointed out that the *Aphis ulmariae* of Schrank, which he here placed in the genus *Siphonophora*, could hardly be the *pisi* of Kaltenbach. He therefore concluded that three species had heretofore been confused with *pisi*, namely *Macrosiphum pisi*, which he had found on garden peas (*Pisum sativum*), sweet pea (*Lathyrus odoratus*) and Medicago; *M. ulmariae* auct., which occurs on meadow-sweet (*Spiraea ulmaria*); and *M. caraganae* Cholod. on *Caragana arborescens*, and gives biological and morphological differences to separate the three. Later, in the same year and in the same publication, Dr. A. Mordwilko (10) gives a lengthy treatise on this insect, which he calls *Macrosiphum pisi* Kalt., and the related species. Eight supposedly distinct species are considered and a table illustrating differences of the following species is given: *M. pisi*, *M. cholodkovskyi*, *M. portschinskyi*, *M. ononis*, *M. gei*, and *M. urticae*. Three species occur on *Spiraea ulmaria*, namely, the *ulmariae* of Schrank, which he considers as belonging to the genus Aphis; *M. cholodkovskyi*, a name given for the species referred to by Cholodkovsky and other authors discussing a Macrosiphum on *Spiraea ulmaria;* and *M. portschinskyi*, a new species. The author is evidently not settled on the identity of *M. ononis* Koch, although at the end of the paper he states that "apparently the last species (*ononis* Koch) must also be recognized as distinct." And, finally, *M. onobrychis* B. de Fonsc. is questionably placed as a synonym of

[1] Numbers (1 to 12) in parentheses refer to the Bibliography of European Literature, p. 55.

pisi. More recently has come a contribution from Prof. Fred. V. Theobald (11, 12) who considers *gei* and *ulmariae* as distinct species, thus corroborating the general conclusions of the two eminent Russian entomologists, Cholodkovsky and Mordwilko. Theobald separates these large green *pisi*-like Macrosiphums into two groups according to the structure of the tip of the cornicle: (1) Those with the tip imbricated, containing *pisi* Kalt., *loti* Theob., and *trifolii* Theob., and (2) the group of closely related species with the tip of the cornicle reticulated, including *ulmariae* Schr., *gei* Koch, and *stellariae* Schr. Further, he is of the opinion that *ononis* Koch is distinct from *pisi*. Our own studies lead us to follow Mordwilko's conclusions. Schrank's description of *Aphis ulmariae* certainly seems to indicate that he was dealing with a true Aphis and not a Macrosiphum.

In 1782 Moses Harris, in his "English Insects," (1), figures an aphis which he calls *Aphis pisum* and gives a nondescript description. Theobald (12) has placed this species as a synonym of *pisi*, but there is nothing excepting the specific name to link it with the aphidid under discussion and it must therefore be placed as a possible synonym of *pisi* but not in the sense of having priority.

In 1841 Sir Oswald Mosley (4) describes *Aphis lathyri* as follows:

> 8th Species: *Aphis lathyri*.—On the Sweet Pea beneath the leaves; colour green, becoming when old of a dark purple; antennæ longer than the body; abdomen acuminated, with tubercles nearly extending to the extremity.

There is little doubt but that this description referred to *pisi*, but even with two years' priority the name *lathyri* can hardly take precedence over the well-established name *pisi* and must be placed in the same category as Harris's *pisum*.

The correct name which should be adopted for this insect is still somewhat questionable, but at this distance we, in America, must follow largely the researches of European aphidologists. *M. pisi* Kalt. must for the present be considered as having priority, although further researches may prove *Aphis onobrychis* B. de Fonsc. to be identical, this species having two years' priority over *pisi*, as stated above. In this connection Mordwilko (10) says:

> The same species of plant louse [referring to *pisi*] was apparently described two years earlier (1841) by Boyer de Fonscolombe and named *Aphis onobrychis*, having been found on *Hedysarum onobrychis*. However, it is still premature to regard these two names as synonyms.

Walker, Buckton, Ferrari, Schouteden, Theobald, and others have made *onobrychis* a synonym of *pisi* but none has given sufficient evidence to support this conclusion. Authors discussing a plant louse on pea under the name *ulmariae* doubtless had in mind *M. pisi*, since it seems to have been fully proven that the true *ulmariae* does not feed on the hosts recorded for *pisi*. Further, we must accept

the interpretations of Cholodkovsky, Mordwilko, and Theobald that species heretofore considered as synonomous with *pisi*, namely *gei* Koch, *ulmariae* Schr., and *ononis* Koch, are good and distinct species and that *onobrychis* B. de Fonsc. is still a doubtful species.

Our own results published herein assure us of the identity of the pea aphis (*pisi* Kalt.) occurring in America and Europe. In America there seem to be only two names, originating here, which can properly be considered synonyms of *pisi* Kalt., namely *destructor* Johnson and *trifolii* Pergande.

The synonymy of *Macrosiphum pisi* Kaltenbach, as we now understand it, is as follows:

Macrosiphum pisi (Kaltenbach).
Aphis pisum Harris.
Aphis lathyri Mosley.
Aphis onobrychis B. de Fonsc.?
Aphis pisi Kaltenbach.
Siphonophora pisi Koch.
Siphonophora ulmariae Passerini (nec Schrank).
Nectarophora pisi Oestlund.
Nectarophora destructor Johnson.
Macrosiphum pisi Schouteden.
Macrosiphum trifolii Pergande.

IDENTITY OF THE SPECIES OCCURRING IN AMERICA.

Macrosiphum pisi was first reported in America by Cyrus Thomas in 1878, although this record has been incorrectly discredited by most subsequent authors. In 1900, following the first noteworthy outbreak of this pest in the United States, Johnson described the species as new, calling it *Nectarophora destructor*. The following year Sanderson reported studies to show that *destructor* is identical with *pisi* of Europe, basing his conclusions partly by comparison with specimens labeled *pisi* from Buckton. Evidently Buckton was confused on this species, since one of the species sent Sanderson was certainly not *pisi*, for the tips of the cornicles were reticulated, a character which separates *pisi* from many closely related forms. Doubtless this error on the part of Buckton led Sanderson to consider certain American species with reticulated cornicles as synonyms or varieties of *pisi*. In 1904 Pergande described a species under the name *Macrosiphum trifolii*.[1] We have had an opportunity to examine the type slide of *trifolii* Perg. and find it to be identical with *pisi*, and our determination has been verified by Mr. Pergande. Notes on the

[1] Prof. Fred. V. Theobald (Theobald, Fred. V. The British species of the genus Macrosiphum, Passerini, Pt. II. *In* Jour. Econ. Biol., v. 8, no. 3, p. 139, fig. 46, Sept. 29, 1913) has described a new species under the name *M. trifolii*, overlooking the fact that the name is preoccupied. We therefore propose for this species *Macrosiphum theobaldii* n. n. It is distinguished from *pisi*, according to Theobald, only by the usually paler green color, the absence of sensoria on antennal segment III of the wingless female, and relatively thicker antennæ, which are rather variable characters for this genus. Winged forms were not observed by Theobald. It is not improbable that this will prove to be *pisi*.

type specimens of *trifolii* are given in the descriptive paragraphs. Pergande listed a variety of hosts attacked by *trifolii*, and although we have not seen specimens other than the types which were collected on *Trifolium pratense*, we doubt the correctness of its occurring on such plants as strawberry, dandelion, wheat, and oats, food plants noted by Pergande.

Through the kindness of Dr. Albert Tullgren, of Sweden, Drs. Mordwilko and Cholodkovsky, of Russia, Prof. F. V. Theobald, of England, and Dr. G. Del Guercio, of Italy, we have been able to compare the American *pisi* with specimens from the foregoing countries and find them to be identical.

PAST HISTORY OF THE PEST AND ITS INJURIES.

IN EUROPE.

For at least a century the "green dolphin," as this insect is commonly known in England, has been a serious pest to peas, vetches, and clover. One of the earliest records of injury is that given us in 1815 by Kirby and Spence (2), who reported that in 1810 "the produce was not much more than the seed sown; and many farmers turned their swine into their pea fields, not thinking them worth harvesting. The damage in this instance was caused solely by the Aphis, and was universal throughout the kingdom, so that a supply for the navy could not be obtained."

In 1876 Buckton (7) writes that this insect "in some years is very destructive to the farm crops. It feeds on a large number of plants, but chiefly it infests the field pea, on the young shoots and leaves of which it clusters by thousands." Thus the pea aphis seems only to have been occasionally and locally injurious in England; but in 1885 that country suffered from a great plague of pea "lice," and this unusual abundance has been correlated with the slight precipitation during that year. In her report for 1885, Miss Ormerod (8) notes that this plant louse particularly damaged peas and vetch.

As has been stated by Mordwilko (10):

> In North Europe the pea louse lets itself be heard from only occasionally. For instance, Kaltenbach (1843–1872) and C. Koch (1857) mention nothing at all about damage by the pea louse. Only E. Taschenberg notes briefly that the pea louse is occasionally very injurious to peas on which it hinders the further growth of the tips of young runners.[1]

Quoting further from Mordwilko (p. 36):

> In Russia as in N. Europe field peas suffer only occasionally from pea lice, namely, when the latter succeeds to increase greatly by the time or before peas come into bloom * * *.

[1] Taschenberg, E. L. Naturgeschichte der wirbellosen Thiere, die in Deutschland sowie in den Provinzen Preussen und Posen den Feld-, Wiesen- und Weide-Culturpflanzen schadlich werden. Bremen, 1865. Also under title: Die der Landwirthschaft Schädlichen Insecten und Würmer.

IN AMERICA.

Dr. Cyrus Thomas was the first to observe and record this species from America (1878, 1879). The authenticity of this record has been doubted by most writers, but we have examined the specimens used by Thomas in drawing up his description (Davis, 1913) and find them to be the *Macrosiphum pisi* of Kaltenbach. Thomas's specimens were collected in Illinois in 1878, which is indicative of its introduction into America some years previous, possibly as much as 10 or 15 years before. Subsequently and previous to 1899, *pisi* was reported by Oestlund (1886), Smith (1890), and Williams (1891).

Macrosiphum pisi, therefore, was introduced into America fully 20 years previous to its appearance in serious numbers and here we have a case analogous to that of the gipsy moth, which was present in this country for about 25 years before it became a pest (Chittenden, 1909a).

Although the losses attributed to this aphidid have been largely to garden peas, still certain other crops have been much injured by it, the actual damage, however, never being apparent as in the case of the garden pea. Among other crops field peas are frequently injured by *pisi*. As early as 1900 Dr. Chittenden (1900b) reported injury to this crop, grown for hay, in Virginia. Mr. G. G. Ainslie records the total destruction of a plat of Canadian field peas at Nashville, Tenn., as early as February 17, in 1911.

The first positive record of injuries to clover in America by this plant louse was noted by Mr. W. G. Johnson, who wrote in 1900 that "hundreds of acres of red clover have been destroyed by it [*M. pisi*]. In one instance, reported to me June 13, 1900, Mr. C. Silas Thomas, of Lauder, Frederick County, Md., stated that the pest had almost entirely ruined 65 acres of red clover. Many other cases of a similar nature were reported or observed by us." Dr. E. D. Sanderson (1900g) reports the occurrence of a plant-louse, presumably this species, which occurred in injurious numbers on crimson clover as early as 1890. In the same paper Sanderson says:

> One of our best farmers, Mr. Frank Bancroft, of Camden, Del., tells me that he has seen what he judges to be the same louse on crimson clover for at least six or seven years [that is, about as early as 1893].

In 1900 Prof. F. M. Webster (1900) observed this insect in abundance on red clover at Wooster, Ohio. Dr. J. W. Folsom (1909) reports injury to red clover in the following words:

> In 1903 the louse killed an immense amount of red clover and weakened much more in Dekalb County [Illinois]. * * * I found on the farm of Mr. A. E. Myers, at Millbrook, August 19, 80 acres of dead clover roots in one field. Not one root in a thousand showed any signs of life, and on the ground were thousands of the cast skins of the aphid. At cutting the lice had been such a nuisance that the men objected to handling the crop. After cutting the clover never revived. In neighboring fields

there were many bare spots where the aphid had killed the clover locally, and in the growing clover were many centers of new infestation, due doubtless to migrant winged females. All of the clover in that part of the country was more or less injured; not only old clover but also the first-year growth. Returning to the same region the following summer to see the consequences of the injury, I did not stay long, for it was hard to find a field of clover anywhere. The farmers reported that the clover had been "winter killed," to their surprise, since the winter had not been a severe one and the clover had often survived worse winters.

Mr. Harold Morrison (1912), discussing the abundance of this insect in Indiana, says:

Two years ago [1910] it was so common in many clover fields near the city [Indianapolis] that the clover remained on the ground for more than a week after cutting without showing signs of curing. The clover stems were so plastered with honeydew that the moisture could not evaporate from them.

We have seen clover fields in Indiana so badly infested that the plants would be covered with the so-called "honeydew," a sticky, sweetish fluid ejected by the aphis from the anus. Walking through such an infested field, one's trousers would appear green, so thickly would they be covered by the plant-lice, and ruined by the honeydew which covered the plants. While it is seldom that fields are killed outright as described by Dr. Folsom, there can be no doubt that the heavy infestations, which are so common, have a decided weakening effect on the plant and much of the winter killing of clover can be traced back to the depredations of the pea aphis. Most probably much damage to clover has been overlooked or attributed to other causes, for while a crop may be injured on large field crops such as clover the injury will be overlooked unless the field is almost killed outright, and subsequent effects, such as the weakening of the vitality of the plants, is too often attributed to "winter killing," as Dr. Folsom has pointed out. Especially may this species be a very dangerous clover pest if the weather conditions are favorable to aphides and a long dry spell retards the growth of the clover.

CHARACTER OF ATTACK.

This aphidid prefers the young tender leaves and stems of its host, but eventually it covers the entire plant. Garden and sweet peas, being succulent plants, are seriously attacked and readily succumb to the depredations of the aphides. Clover, particularly red clover, on the other hand, is able to withstand considerable injury, but, as has been noted, even this plant is not free from serious damage; in fact entire fields of clover are sometimes destroyed.

EFFECTS ON CATTLE OF FEEDING THEM INFESTED CLOVER.

We have no definite reports of injury to cattle by feeding clover hay which has been heavily infested with aphidids; indeed, we have been informed by cattle feeders that such clover, which has a slightly

sweetish taste because of the honeydew covering it, is rather relished by cattle. Mr. Lawson Caesar (1911) reports that feeding cattle with infested vines was supposed by one farmer to be the cause of the death of some of his cattle, but there seems to be no proof and the conclusions were probably incorrect.

DISTRIBUTION AND ORIGIN.

As will be seen on the accompanying map (fig. 1), this aphidid is generally distributed over the United States and southern Canada, especially in the eastern half, where it is more or less destructive every year. It is likewise generally distributed throughout Europe. Theobald (12) reports this species from Natal, South Africa, and Dr. B. Das (in litt.) has found it plentiful in British India.

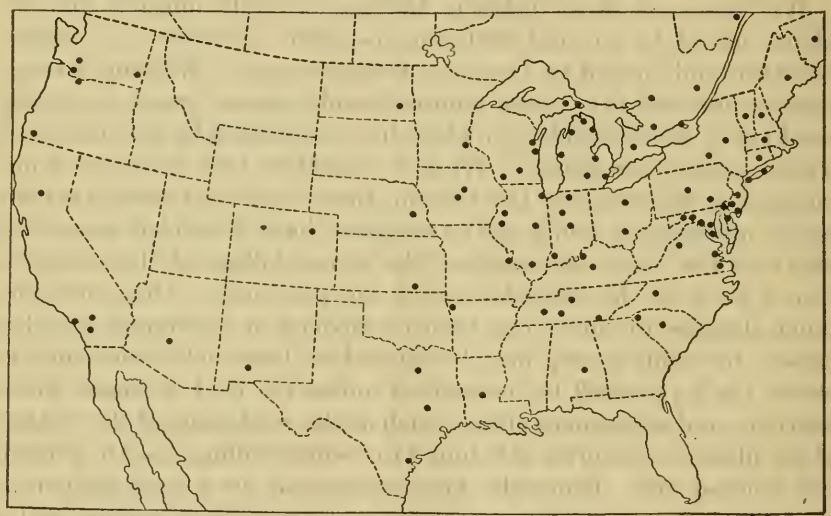

FIG. 1.—Map showing the known distribution of the pea aphis (*Macrosiphum pisi*) in America. (Original.)

As an injurious species it occurred first in America along the Atlantic coast. The following year (1900) it was very destructive in Wisconsin and Michigan, and has since worked its way westward to the Pacific coast. Recently Mr. F. C. Bishopp has sent in specimens from Texas, where it seems to have gained a strong foothold.[1]

The fact that *M. pisi* was first observed in this country within comparatively recent years and was first apparent in destructive

[1] Mr. Bishopp has kindly given the writer permission to quote his letter accompanying the specimens, under date of Aug. 4, 1914, which reads as follows:

The pea aphis was observed to be doing damage to English peas (garden peas) in experimental plats just east of Dallas, shortly after the middle of May (1914). The peas began blooming about April 30. On May 26 the growth of the peas was practically stopped and many vines turned yellow on account of the exceedingly heavy infestation of aphides. On May 31 practically all of the pea vines were dead without having produced a single pod. During the first three weeks of June, lady beetles, principally *Hippodamia convergens*, were observed to be destroying the aphides in great numbers, and a few of the pea vines were almost cleared of the "lice" and started to grow a little; however, they never made any fruit.

Mr. Bishopp further stated that the sweet peas and garden peas throughout the city of Dallas were practically destroyed.

numbers only 15 years ago is evidence that it is of exotic origin, but further evidence of the fact that it is an introduced species may be obtained by a study of the origin of its host plants. Either the sexual forms or eggs of *pisi* have been found on alfalfa (*Medicago sativa*), *M. falcata*, red clover (*Trifolium pratense*), everlasting pea (*Lathyrus sylvestris*), *Lathyrus angustifolius*, and *L. latifolius*. All of these, according to De Candolle,[1] originated in Europe, Asia, or northern Africa; indeed, all of the known cultivated hosts of *pisi* had their origin in one or the other of these continents, and from what can be learned from other writers the uncultivated host plants as well are of exotic origin. Very probably the original host of *pisi* was one of the perennials, either *Medicago sativa* or *Trifolium pratense*, or perhaps *Onobrychis sativa*, if the aphis occurring on this plant should prove to be *pisi*. Of these three hosts *M. sativa* is supposed to be the oldest in cultivation, for, according to De Candolle, it has been cultivated for more than 2,000 years, while the other two have been in cultivation less than 2,000 years. From the fact that *M. sativa* is not universally and commonly attacked by *pisi*, while *T. pratense* is, we can with reasonable certainty assume that the latter was the original host of this legume aphidid. De Candolle has shown us that *T. pratense* is a native of Europe, Algeria, and western temperate Asia, while *M. sativa* is a native of western temperate Asia, and *Onobrychis sativa* originated in temperate Europe, south of the Caucasus. Speaking further of red clover he says:[2] "*Trifolium pratense* is wild throughout Europe, in Algeria, on the mountains of Anatolia, in Armenia, and in Turkestan, in Siberia toward the Altai Mountains, and in Kashmir and the Garhwal." Of alfalfa he says (p. 103): "It has been found wild, with every appearance of an indigenous plant, in several provinces of Anatolia, to the south of the Caucasus, in several parts of Persia, in Afghanistan, in Beluchistan, and in Kashmir."

From these we may assume with a fair degree of accuracy that *Macrosiphum pisi* originated in Europe or Asia, most probably in western temperate Asia or southeastern Europe.

FOOD PLANTS.

The pea aphis commonly feeds on the clovers—especially red and crimson clover—garden, grass, Canadian field, and sweet peas, vetch, and, as will be seen later, not infrequently on alfalfa. Shepherd's-purse (*Bursa bursa-pastoris*) has been repeatedly mentioned as a host, but experiments conducted by Mr. E. H. Gibson of the cereal and forage crop insect investigations, and our own tests, have given negative results. Further the writer has examined a number of different collections of Macrosiphum from this host, invariably

[1] Candolle, Alphonse de, Origin of Cultivated Plants, p. 468. London, 1884. [2] Loc. cit., p. 105.

labeled *M. pisi* or its equivalent, and in no case has the true *pisi* been found. On the other hand, Dr. Edith M. Patch had no difficulty in getting this insect to live contentedly on shepherd's-purse. Theobald (11) lists shepherd's-purse (*Bursa bursa-pastoris*) as a host, but later in his paper says: "Colonies now and then occur on the shepherd's-purse, but I have never known them to survive any length of time." The species reported for lettuce as *M. pisi* or a variety of that species by Sanderson and others is an entirely different plant-louse. Doubtless the species collected on nettle (Urtica) and referred to this species by Oestlund is something else, and the same can be said of the records of this aphidid from beet.

In 1900 Dr. Chittenden reported tests made by Mr. Theodore Pergande to colonize this insect on the following hosts, but with negative results in each case: *Sonchus asper*, dandelion, shepherd's-purse, *Sisymbrium officinale*, and dock.

Dr. Edith M. Patch (1911) has reported a series of insectary host-plant tests for *M. pisi*, which may be briefly summarized as follows: Transfers from peas (*Pisum sativum*) to potato (*Solanum tuberosum*), to barley, wheat, oats, purslane (*Portulaca oleracea*), beets, and squash were wholly negative; from peas to red clover partially positive, and from peas to shepherd's-purse (*Bursa bursa-pastoris*) positive.

During the late summer of 1911 Mr. C. W. Creel, of this bureau, and the writer conducted a number of transfer experiments, with the following results: From red clover to cowpeas, cultivated buckwheat, wild buckwheat (*Tiniaria cristata*), wild morning-glory (*Convolvulus arvensis*), fleabane (*Leptilon canadense*), pepper-grass (*Lepidium* sp.), wheat, alfalfa, yellow sweet clover (*Melilotus officinalis*), and cinquefoil (*Potentilla* sp.), the results were negative; from red clover to soy beans were partially positive and indicated that the insect might survive and reproduce on young tender plants; from red clover to red clover, garden peas, and white sweet clover (*Melilotus alba*) the insect transferred readily and fed and reproduced contentedly. In Chicago, Ill., we found it breeding very abundantly on tender succulent shoots of *Melilotus alba* growing under greenhouse benches.

Theobald (12) attempted to colonize the species on willow, raspberry, clematis, clover, and Lathyrus, but was successful with only the two last-named plants.

Mr. C. E. Sanborn (1904) reports this aphidid from rose, but in a recent letter he writes: "*Macrosiphum pisi* has been correctly recorded as being taken on rose. I doubt, however, if rose should be considered as a regular food plant of this insect." We have repeatedly attempted to colonize *pisi* on rose, but without success, and there seems to be no reasonable question but that the specimen collected by Sanborn on rose was a stray migrant.

Mr. D. T. Fullaway (1910) reports having taken *M. trifolii* Perg. (=*pisi*) on *Sonchus oleraceus* in Hawaii, but an examination of the specimens through the kindness of Mr. Fullaway shows them to be something other than *pisi*. We have also had the privilege of examining the specimens collected and recorded by Mr. W. M. Davidson (1909) as *M. pisi* on *Urtica holosericea*, and they prove to be of another species.

We have a number of individual office records reporting *M. pisi* on alfalfa. Among these, specimens for which were examined by the writer, are the following: Mr. C. N. Ainslie collected it on this host at Prairie Grove, Ark., March 21, 1907, all stages being found. An examination of this material shows a mixture of *M. pisi* and *M. creelii*, although the former species predominates. Mr. Ainslie also collected this aphidid at Arlington, Va., April 6, 1908, on alfalfa. Mr. V. L. Wildermuth collected it on alfalfa at Holtville, Cal., April 17, 1912, and at Muirkirk, Md., April 28, 1909. At the latter place the infested alfalfa had a wilted appearance, and because of their abundance this injury was supposed to be caused by the plant-lice. Probably the most noteworthy example of *pisi* occurring on alfalfa was recorded by Mr. J. A. Hyslop, who, on November 12, 1912, observed these aphides swarming in an alfalfa field near Funkstown, Md. At this time very few viviparous forms were observed; the males and oviparous females predominated, and a few days later the black shiny eggs were found abundant on the alfalfa leaves. In this same field Mr. Hyslop observed the aphides abundant in May (1913), but in August not a single individual was found. Further observations were made in this field by Mr. C. M. Packard in October (1913), at which time the aphides were again abundant. Mr. J. T. Monell has determined as this species plant-lice collected on alfalfa at Wellington, Kans., May 4 to July 30, 1909, by Mr. E. O. G. Kelly. In all cases where this aphidid occurred on alfalfa it was found on the young terminal buds and leaves.

The following is a list of the authentic hosts of *M. pisi* as recorded in America. Although shepherd's-purse is retained as a host of this plant-louse, we have never seen specimens of this species collected on that plant. Shepherd's-purse (*Bursa bursa-pastoris*), lentil (*Ervum* sp.), sweet pea (*Lathyrus odoratus*), grass pea (*L. sativus*), alfalfa (*Medicago sativa*), white sweet clover (*Melilotus alba*), garden pea and field pea (*Pisum sativum*), crimson clover (*Trifolium incarnatum*), red clover (*T. pratense*), white clover (*T. repens*), vetches or tares (*Vicia ludoviciana*, *V. gigantea*, *V. villosa*, et al.).

The following reliable hosts have been recorded by European writers. Many of the recorded hosts, such as Geum, Ulmaria, etc., are certainly incorrect, while others are highly improbable, and as they have not been corroborated since the correct identity of *pisi* has been understood, they are not here included: Shepherd's-purse

(*Bursa bursa-pastoris*), *Chaerophyllum sylvestre*, *C. temulum*, lentil (Ervum), *Lathyrus angustifolius*, sweet pea (*L. odoratus*), *L. latifolius*, *L. pratensis*, flat pea (*L. sylvestris*), *Medicago falcata*, alfalfa or lucern (*M. sativa*), *Onobrychis* sp. (?), *Ononis repens* et spp. (?), garden pea and field pea (*P. sativum*), *Trifolium filiforme*, alsike clover (*T. hybridum*), red clover (*T. pratense*), white clover (*T. repens*), vetch (*Vicia cracca*, *V. sativa*, *V. sepium*).

Dr. B. Das, of the Government college at Lahore, India, writes (*in litt.*) under date of December 18, 1913, as follows:

> I have collected it [*M. pisi*] from Bengal, Behar, United Provinces, and the Punjab. Though not actually collected by myself, I believe it is present in other parts of India as well. What looked like a bad attack on a few plants was observed once on that beautiful flower known as "Glory flower" or "Parrot's beak" (*Clianthus dampieri*). The hosts of this species, so far known to me besides the above are: *Alhagi maurorum*, *Melilotus alba*, *Medicago sativa*, *M. falcata*, *Lathyrus odoratus* (rather bad once in Behar), *Peganum harmala*, and *Dolichos lablab*.

DESCRIPTION.

STEM-MOTHER.

Young hatching from egg, before first molt and not over 24 hours old.—Body a very pale pea green and dorsum entirely covered with a fine and uniform whitish pulverulence which gives the insect a terre verte color. Head with a dusky patch on each side of the dorsal median line, which is, however, indistinct with the pulverulent covering. Eyes black. Antennæ four-segmented and blackish green, the last segment apparently black. Legs blackish green, the distal four-fifths of the hind tibiæ covered with a bloom giving them a whitish appearance and as if covered with a mold. Cornicles blackish green, slightly paler at the base and a black ring marking the rim of the opening at apex. Cauda not visible.

Measurements of a single individual, made immediately after mounting in balsam and before shrinkage occurs: Length of body, 0.956 mm., width, 0.487; length of cornicles, 0.0695 mm., width, 0.037; antennæ (the two antennæ measured exactly alike), segment I, 0.052 mm.; segment II, 0.043; III, 0.191; IV, base, 0.078; IV, filament, 0.178; total length, 0.542 mm.

Wingless adult (fig. 2).—(Described from four specimens, Apr. 24, 1913.) Body color pale green, the abdomen bearing several dark reddish dots which are the eyes of the embryos within her body. The dorsal and ventral surfaces show a distinct reticulation in living individuals, head bearing a faint pulverulence. Eyes dark red. Antennæ more than two-thirds the length of the body but not reaching to the base of cornicles; segments I and II concolorous with head and semitranslucent, the remaining segments semitransparent with a faint brownish green tint, excepting the tips of III and IV, distal

fourth of V, distal half of VI, base and all of filament of VI, which parts are black; segment III sometimes, but not always, bearing a small inconspicuous sensorium near its base and the usual sensoria at distal end of V and VI base. Beak just reaching coxæ of second pair of legs. Legs with femur very pale green and semitransparent; tibia with basal half pale semitransparent, the distal half with a faint brownish tint and the tip black; tarsus black. Cornicles reaching tip of cauda (of the four specimens examined the cornicles reached a little beyond the tip of cauda in three specimens and not quite to the tip in the fourth specimen), concolorous with body at base, becoming paler and semitransparent toward the apex, the tip blackish; cylindrical and slender; noticeably widened at base and the tip imbricated. Cauda ensiform and typical of the genus, and concolorous with body.

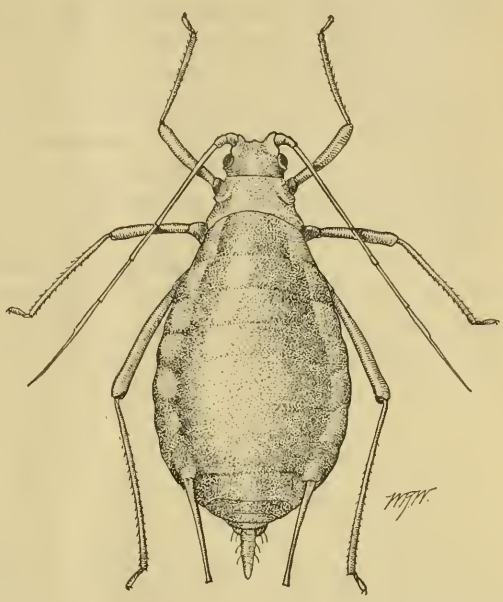

FIG. 2.—*Macrosiphum pisi:* Adult stem-mother. Much enlarged. (Original.)

Measurements from two specimens immediately after placing alive in balsam and before shrinkage occurs: Length of body, 2.63 mm., to tip of cauda, 3, width, 1.45; length of cornicles, 0.74 mm., of cauda, 0.44. Measurements of antennal segments:

I.	II.	III.	IV.	V.	VI, base.	VI, filament.
Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.156	0.069	0.695	0.348	0.469	0.235	0.522
.156	.078	.695	.348	.452	.243	.539
.139	.078	.626	.287	.400	.209	.469
.139	.087	.634	.296	.400	.209	.469

SUMMER VIVIPAROUS GENERATION.

First instar, before first molt and about 1 hour old (fig. 3).—(Described from six specimens, Aug. 20–21, 1912.) Head and thoracic segments whitish with a pale greenish tint; remainder of body pale green excepting those segments posterior to and including the segment

bearing the cornicles, which are of a decided bright yellow tint. Antennæ five-segmented, reaching a little beyond tip of body, segments I and II concolorous with head or paler, the remaining segments whitish semitransparent with the tips of III, IV, and basal part of V dusky. Eyes bright red. Legs concolorous with antennæ, excepting tarsus which is dusky. Cornicles concolorous with antennæ the tip dusky, slightly narrowed at tip, and reaching beyond tip of abdomen. Style not visible.

FIG. 3.—*Macrosiphum pisi:* First instar of viviparous generation. Much enlarged. (Original.)

Measurements from two specimens, immediately after placing in balsam and before shrinkage occurs: Length of body, 0.91 mm., width, 0.40; length of cornicles, 0.139 mm. Measurements of antennal segments:

I.	II.	III.	IV.	V base.	V filament.
Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.06	0.05	0.19	0.18	0.087	0.39
.07	.05	.208	.208	.094	.45
.07	.05	.208	.208	.100	.45
.07	.05	.208	.208	.100	.45

Second instar, after first molt and 50 to 60 hours old.—(Described from four specimens, Aug. 19–22, 1912.) Entire body pale green; eyes red; antennæ reaching a little beyond tip of abdomen; segments I and II pale green and somewhat transparent; III, IV, and base of V pale, semitransparent, with the tips dusky; filament of VI blackish; segment III sometimes with a dusky ring near middle, but not constricted. Beak reaching coxæ of second pair of legs. Legs with femur very pale green, the tip dusky, tibia pale, becoming dusky toward tip, the tip blackish, and tarsus black. Cornicles pale, semitransparent, becoming pale dusky near apex, the extreme tip black. Cauda concolorous with body.

Measurements from two specimens, immediately after placing in balsam and before shrinkage occurs: Length of body, 1.16 mm., width, 0.53; length of cornicles, 0.25 mm. Measurements of antennal segments:

I.	II.	III.	IV.	V base.	V filament.
Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.104	0.060	0.348	0.261	0.129	0.765
.095	.069	.330	.270	.139	.608
.104	.060	.348	.270	.139	.600
.095	.060	.348	.278	.139	.608

Third instar, after second molt and 75 to 97 hours old.—(Described from three specimens, Aug. 20–23, 1912.) Body pale green, the anterior portion, including head, slightly paler or yellowish green; some

specimens pale yellow-green at posterior end, becoming whitish green toward anterior end. Eyes maroon red. Antennæ a little longer than body; 6-segmented; segment I pale green; II pale green, with a faint brownish tint; III, IV, and V pale, sometimes with a faint brownish tint, and the tips dusky to blackish; base of VI pale brownish to dusky, becoming blackish at the tip; filament of VI blackish. Beak reaching to coxæ of second pair of legs. Legs with femur pale greenish yellow to greenish, the apex sometimes pale brownish, tibia pale with a slight duskiness and the tip blackish, tarsus black. Cornicles reaching just to or a little beyond tip of cauda. Cornicles pale green to yellowish green at base, becoming pale dusky toward apex, the extreme tip black. Cauda concolorous with body. Cornicles, cauda, and antennæ usually semitransparent.

Measurements from one specimen, immediately after placing in balsam and before shrinkage occurs: Length of body, including cauda, 1.70 mm, width, 0.64; length of cornicle, 0.40 mm. Measurements of antennal segments:

I.	II.	III.	IV.	V.	VI base.	VI filament.
Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.12	0.07	0.278	0.278	0.370	0.174	0.73
.12	.07	.268	.295	.382	.157	.73

Fourth instar, after third molt and between 127 and 128 hours old.—(Described from two specimens, Aug. 19–24, 1912.) Body pale green, sometimes with an indistinct yellowish area at the base of each cornicle, the head and thoracic segments sparsely covered with a whitish pulverulence which gives them a paler green color. Eyes maroon red. Antennæ reaching beyond tip of cauda; segment I concolorous with head, II concolorous with head or with a faint brownish tint; III, IV, V, and base of VI pale brownish green, with the tips blackish; filament of VI blackish. Legs with femur pale green at base, becoming faintly dusky toward apex, tibia pale brownish with tip blackish, tarsus black. Cornicles reaching a little beyond tip of cauda, pale green with the tip blackish. Cauda concolorous with body.

Measurements from one specimen, immediately after placing in balsam and before shrinkage occurs: Length of body, 2 mm., length including cauda, 2.25, width, 0.92; length of cornicles, 0.61 mm.; length of cauda, 0.25 mm. Measurements of antennal segments:

I.	II.	III.	IV.	V.	VI base.	VI filament.
Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.15	0.07	0.487	0.469	0.504	0.208	0.887
.15	.07	.504	.452	.504	.208	.887

Adult wingless viviparous female.—(Described from four specimens reared on red clover, Aug. 18–22, 1912.) (Fig. 4.) Entire body pale gradually blackening toward tip; VI dark brown to black; segment green, the anterior part, including head and usually the first and second thoracic segments, as a rule paler. The red eyes of the embryos within the body are almost always visible through the dorsal body wall. As seen through the binocular the living individual appears slightly roughened and reticulated. Eyes dark reddish brown. Antennæ (fig. 4, *a*) on prominent tubercles; reaching beyond tip of cauda; filament of segment VI the longest, it being noticeably longer than III; segments I and II concolorous with head; III and IV dusky

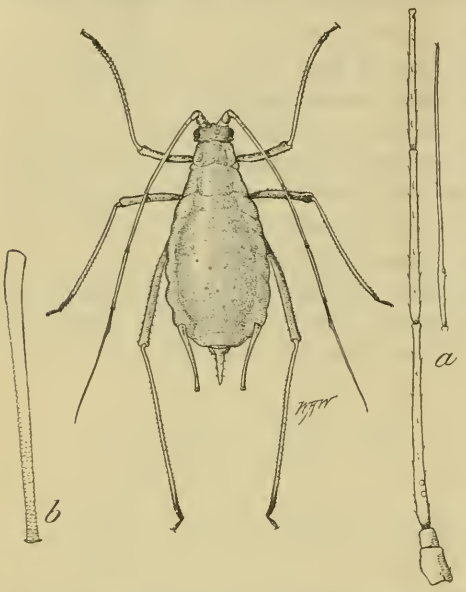

FIG. 4.—*Macrosiphum pisi:* Adult wingless female of viviparous generation, much enlarged; *a*, antenna, and *b*, cornicle, of same, more enlarged. (Original.)

greenish to pale brownish, with the tips blackish; V darker, gradually blackening toward tip; VI dark brown to black; segment III with one or two, and sometimes three, circular sensoria near the base; segments V and base of VI with the usual distal sensoria; hairs short and sparse. Beak reaching to coxæ of second pair of legs. Legs long and slender, moderately hairy; femur pale green with a slight brownish tint toward apex, joint of femur and tibia dusky; tibia pale green, with a slight brownish tint, and the tip blackish; tarsus black. Cornicles long and slender, broadest at base, tip imbricated and no sign of reticulation, just reaching to tip of cauda, pale green at base, paler or with a faint brownish tint toward apex, the extreme tip black. Cauda concolorous with body, ensiform, and

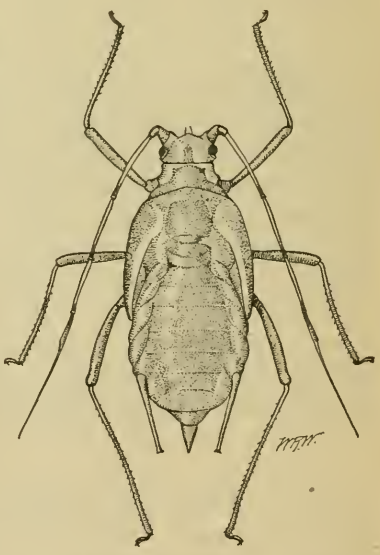

FIG. 5.—*Macrosiphum pisi:* Pupa of viviparous generation. Much enlarged. (Original.)

typical of the genus; more than half as long as the cornicles, bearing a number of moderately long hairs.

Measurements (averages) from three specimens, taken immediately after placing in balsam and before shrinkage occurs: Length of body, 2.67 mm., length to tip of cauda, 3.22; width, 1.24; cornicles, 0.98 mm.; cauda, 0.59 mm. Measurements of antennal segments:

I.	II.	III.	IV.	V.	VI, base.	VI, filament.
Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.191	0.087	0.904	0.713	0.713	0.261	1.130
.191	.087	.930	.730	.713	.261	1.026
.191	.087	.817	.678	.696	.261	1.026
.191	.087	.800	.678	.626	.235	.974
.191	.087	.887	.696	.678	.261	.991
.174	.087	.870	.696	.696	.261	1.026

Pupa (*fourth instar*) (fig. 5).—(Described from three specimens, Aug. 22, 1912). Entire dorsum pale green, sometimes with a delicate white pulverulence. Wing pads pale greenish with faint brownish border, the tips darker brown. Underside of body with a distinct white pulverulence. Eyes maroon red. Antennæ with segments I and II concolorous with head; III, IV, and V pale with slight brownish tint and tips blackish; VI entirely blackish. Beak not reaching coxæ of second pair of legs. Legs with femur pale green, tibia pale with slight brownish tint and blackish at the tip, tarsus black. Cornicles pale green at base, becoming whitish with a faint duskiness, the tips black; cauda concolorous with body.

Measurements (average) from three specimens, immediately after placing in balsam and before shrinkage occurs: Length of body, 2.94 mm., width, 1.19; length of cornicles, 0.63 mm. Measurements of antennal segments:

I.	II.	III.	IV.	V.	VI, base.	VI, filament.
Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.139	0.078	0.556	0.495	0.539	0.209	0.834
.139	.078	.539	.487	.548	.209	.852
.139	.069	.487	.469	.513	.209	.808
.139	.078	.461	.443	.487	.209	.817
.156	.078	.539	.522	.539	.209	.800
.148	.078	.556	.513	.565	.200	.887

Winged viviparous female (fig. 6).—(Described from three specimens reared on red clover, Aug. 22 and Dec. 11, 1912.) Head pale yellow-green, thoracic shield shining yellow-green, other parts of thorax concolorous with the head, and abdomen pale green with the eyes of the embryos showing through the skin of the dorsum as in the case of the adult wingless female. Eyes bright red. Antennæ (fig. 6, *a*) placed on large frontal tubercles, and reaching beyond tip of cauda;

filament of segment VI longest, it being noticeably longer than III; segments I and II of a darker green color than body, III with the extreme base pale, the remainder of that segment brownish with the extreme tip black; IV pale brown at base gradually changing to blackish brown toward the apex, the extreme tip black; V and VI blackish to black, bearing a moderate number of rather short, fine hairs; segment III with 11 to 22 (one apparently abnormal specimen had but 9 and 10 sensoria, respectively, on its two antennæ), with an average of 15.5 for 36 examples examined, circular sensoria arranged in a row but not extending quite to the tip, the distal one-fifth of the segment bare, the usual distal sensoria on V and base of VI. Beak

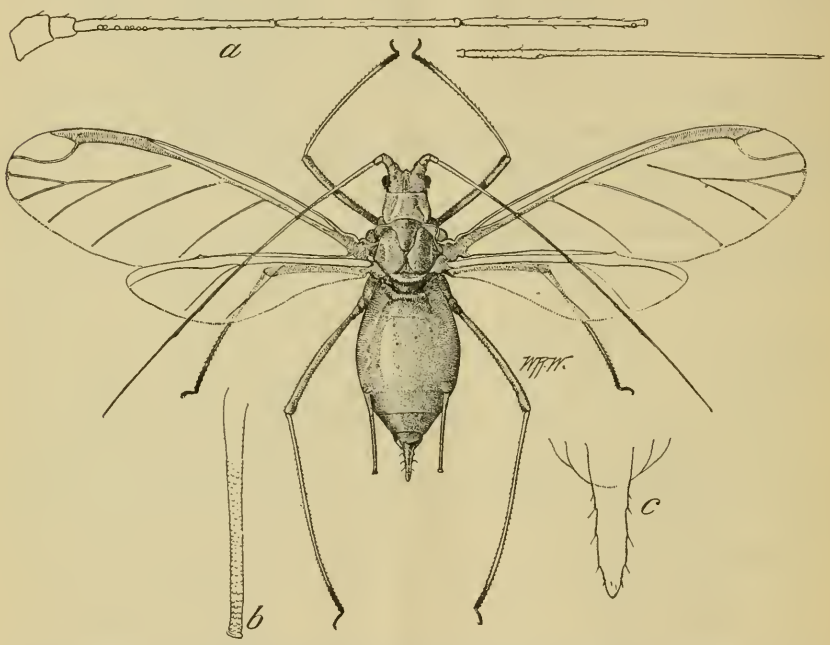

FIG. 6.—*Macrosiphum pisi:* Winged female of viviparous generation, much enlarged; *a*, antenna, *b*, cornicle, and *c*, cauda, of same, more enlarged. (Original.)

not quite reaching coxæ of second pair of legs. Wings clear, veins slender and brownish, the second branch of the media varying somewhat but usually about equidistant from tip of wing to the point where the media first branches; hind wings with normal venation. Legs long and slender; femur pale green on basal half, becoming dusky to blackish toward tip; tibia pale greenish with a faint brownish tint and the apex black; tarsus black. Cornicles (fig. 6, *b*) long and slender, reaching beyond tip of cauda, widest at the base, basal third concolorous with the abdomen, remainder dusky and the extreme tip black, imbricated, and no sign of reticulation at the tip. Cauda concolorous with the abdomen.

Measurements (average) from three specimens, immediately after placing in balsam and before shrinkage occurs: Length of body, 2.79 mm., to tip of cauda, 3.18., width, 1.11; length of wings, 3.51 mm., width, 1.16; length of cornicles, 0.84 mm.; length of cauda, 0.46 mm.; length of hind tibia, 2.32 mm. Measurements of antennal segments:

I.	II.	III.	IV.	V.	VI, base.	VI, filament.
Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.156	0.069	0.826	0.721	0.748	0.304	1.095
.156	.078	.817	.730	.748	.296	1.061
.....	.....	1.006	.716	.735	.329	1.006
.....	.....	1.006	.677	.735	.310	.987
.....	.....	.968	.658	.658	.310	.968
.....	.....	1.045	.658	.677	.290	.....

SEXUAL FORMS.

Winged male (fig. 7).—(Described from two specimens, Dec. 4, 1912.) Head and prothoracic segment gamboge with a dusky to

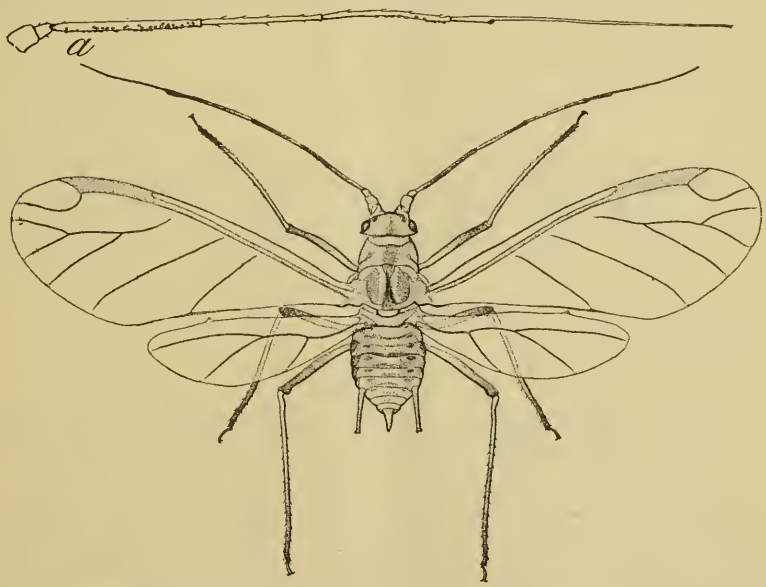

FIG. 7.—*Macrosiphum pisi:* Winged male, much enlarged; *a*, antenna of same, more enlarged. (Original.)

brownish longitudinal median dorsal marking which does not extend quite to tip of head. Thoracic shield brownish with interstices concolorous with head. Abdomen pale green with pale dusky markings as shown in the illustration (fig. 7) and the segments posterior to the cornicles pale yellowish green. Eyes very dark red, almost black. Antennæ (fig. 7, *a*) noticeably longer than body; filament of VI longer than III; entire antenna blackish excepting segments I and II and

small area at base of III, which are pale dusky; sparsely covered with delicate, inconspicuous hairs; segment III bearing 40 to 50 irregularly placed circular sensoria, IV bare, V with 10 to 15 circular sensoria, not including the usual distal one, more or less in a row but more thickly placed toward the apex; base of VI with the usual distal ones. Beak whitish yellow, the tip black; reaching beyond the coxæ of the first pair of legs but not to the middle coxæ. Wings as in the viviparous female. Legs long and slender, the femur pale yellowish to yellowish green, becoming blackish on the distal third, tibia pale brown and the tip black, tarsus black. Cornicles as in viviparous forms, pale with a slight duskiness and the tip blackish. Cauda ensiform and bearing moderately long hairs as in other forms, and pale dusky to dusky in color.

Measurements of body dimensions not made from living specimens and mounted individuals are slightly shriveled. The male is considerably smaller than the viviparous female. Measurements from specimens mounted in balsam except as noted: Length of body, 1.4 mm., to tip of cauda, 1.55, width, 0.52; length of wing, 2.87 mm., width, 1.04; length of cornicle, 0.38 mm.; length of cauda, 0.20 mm. Measurements of antennal segments:

I.	II.	III.	IV.	V.	VI base.	VI filament.
Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.156	0.069	0.696	0.539	0.626	0.217	[1] 0.852
.156	.069	.696	.547	.609	.243	[1] 1.008
.148	.069	.626	.435	.504	.217	[2] .852
.148	.069	.626	.400	.495	.191	[2] .800
.139	.069	.....	.435	.469	.174	([2])

[1] Measured immediately after placing in balsam.
[2] Specimens killed in 70 per cent alcohol, mounted in balsam the following day, and measured immediately afterwards.

Wingless male (fig. 8).—(Described from two specimens, one observed in copula, October 18, 1911.) Head dusky brown, thoracic segments and first abdominal segment pale yellowish; remainder of abdomen pale green with dusky markings as follows: One spot on each side, dorsolateral in position, on the thoracic segments and the first five or six abdominal segments, those on the first two thoracic segments very faint, the others gradually larger, those on the first three abdominal segments being transverse markings rather than simple dots, and the markings on the following abdominal segments, dots or small circular spots. Antennæ situated on prominent frontal tubercles; much longer than the body; sparsely hairy; filament of segment VI longer than III; I and II dusky brown to blackish; III black, excepting paler extreme base; IV dark brownish and black at tip; V black, excepting a small portion at the base which is brownish, and VI black; segment III bearing 47 to 57 irregularly

placed circular sensoria; IV bare; V with 14 to 18 circular ones, not including the usual distal sensorium, in a row on the distal two-thirds; base of VI with the usual ones. Beak reaching about to coxæ of second pair of legs. Legs long and slender, the femur blackish excepting basal third, which is pale; tibia pale brown except tip, which is black, and the tarsus black. Cornicles as in winged male, pale at base, becoming faintly dusky toward the tip; the apex black. Cauda pale green and agreeing with that of the winged male. Measurements (averages) from two specimens mounted in balsam, bodies slightly shriveled: Length of body, 1.55 mm., to tip of cauda, 1.72, width, 0.58; length of cornicles, 0.57 mm.; length of cauda, 0.26 mm. Measurements of antennal segments:

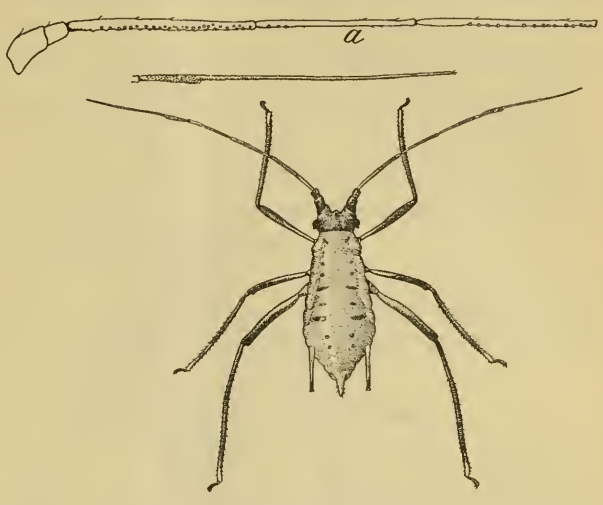

FIG. 8.—*Macrosiphum pisi:* Wingless male, much enlarged; *a*, antenna of same, more enlarged. (Original.)

I.	II.	III.	IV.	V.	VI base.	VI filament.
Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.156	0.087	0.817	0.713	0.748	0.252	1.061
.156	.087	.852	.678	.730	.261	1.009
.156	.087	.817	.651	.748	.269	.991
.156	.087	.817	.661	.739	.243	1.043

Wingless oviparous female (fig. 9).—(Described from two specimens, December 12, 1912.) General color pale pea green or even yellowish green, the head paler and the abdomen posterior to the cornicles with a yellowish tint in some individuals. The eggs within the body often show through the dorsal abdominal wall. Eyes dark red. Antennæ placed on prominent frontal tubercles; reaching to or a little beyond tip of body; very sparsely hairy; filament of segment VI longest; sensoria usually as in the wingless viviparous female, that is, only 1 or 2 sensoria at the base of segment III, but we have found exceptions where segment III bore as many as 10 sensoria in a row; segments I and II pale green or yellowish green,

the remaining segments pale with a faint greenish tint and the tips of III, IV, V, and all the base of VI dusky and filament of VI black. Legs pale green, the tips of tibia and all of the tarsus blackish, basal two-thirds to three-fourths noticeably swollen and bearing numerous small circular sensoria (fig. 9*b*); cornicles as in other forms, just reaching to tip of cauda, pale with slight greenish tint and the tip dusky to blackish. Cauda pale green or yellowish. Measure-

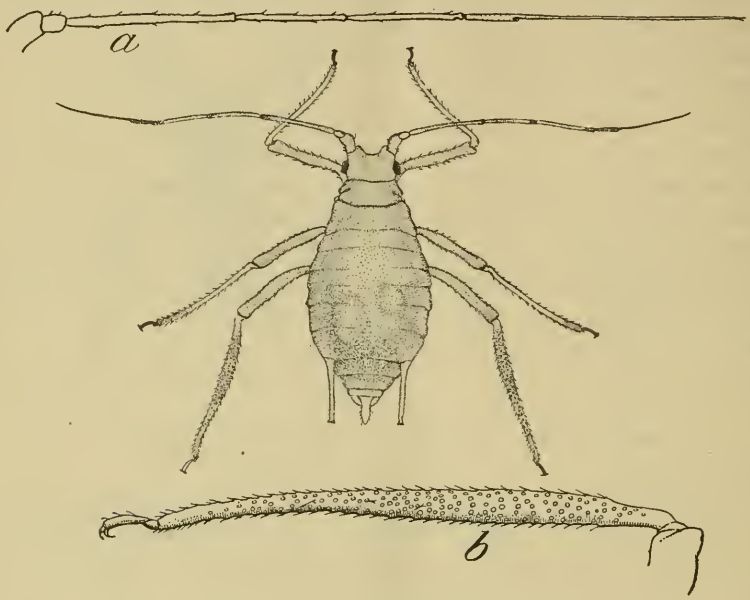

FIG. 9.—*Macrosiphum pisi:* Oviparous female, much enlarged; *a*, antenna, and *b*, hind tibia, of same, more enlarged. (Original.)

ments taken immediately after mounting: Length of body, 1.82 mm. (Another individual, apparently unfertilized, but with abdomen abnormally distended with eggs, measured 2.21 mm. in length and 1.28 mm. in width.) Length of body to tip of cauda, 1.97 mm., width, 0.93; cornicles, 0.46 mm.; cauda, 0.21 mm. Measurements of antennal segments:

I.	II.	III.	IV.	V.	VI base.	VI filament.
Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.139	0.078	0.487	0.348	0.391	0.209	0.661
.139	.078	.494	.348	.400	.209	.643
.139	.078	.696	.435	.522	.234	.817
.156	.069	.748	.435	.522	.252	.800

Egg.—The egg is pale to bluish green and shining when first laid, gradually changing to jet black. It is elliptical oval, and measures 0.75 to 0.80 mm. in length and 0.35 to 0.40 mm. in width.

Sexuparæ.—What we have supposed to be wingless sexuparæ, that is, viviparous females which give birth to the sexual forms, differ from the summer wingless viviparous females only by a larger number of sensoria borne on antennal segment III. There is no positive assurance that these are sexuparæ but all of our mounted specimens showing this character were collected in September or later. Likewise, wingless viviparous females, collected in Russia during September by Dr. A. Mordwilko and sent us by Dr. N. Cholodkovsky, bear a similar number of sensoria. Six antennæ of specimens collected at La Fayette, Ind., in October bear 10, 7, 8, 9, 13, and 16 sensoria, respectively, on segment III, and eight antennæ of specimens collected in Russia in September bear 21, 22, 14, 7, 9, 9, 9, and 10 sensoria respectively, on segment III.

Aberrant form.—In the fall it is not uncommon to find a form which has the hind tibia swollen and bearing numerous sensoria, a character of the oviparous female, but instead of eggs the body often contains living young.

DESCRIPTIVE NOTES ON TYPE OF TRIFOLII PERG.

The type slide of *M. trifolii* Perg. which we examined September 5, 1911, bears the following data on label: "7205 (Nectarophora) Macrosiphum trifolii n. sp. Perg. on clover, Charlottesville, Va., Apr. 28, 1900." There are five winged viviparous females on the slide, the bodies of which are shrunken. The second branch of the median vein branches at a distance from the tip of the wing varying from one-half or less to three-eighths the distance from the tip to where it first branches, but usually the branching is nearer to the tip than to the point where the media first branches. Cornicles imbricated over their entire length but more distinctly near tip; the tip not reticulated. From the balsam specimens the tips of the cornicles appear to have been dusky in life, the remainder concolorous with body. Measurements of the antennal segments, cornicles, and cauda were taken as follows:

Antennæ.

I.	II.	III.	IV.	V.	VI base.	VI filament.
Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.156	0.069	0.678	0.556	0.574	0.243	Broken
.156	.078	.609	.522	.539	Broken	Broken
.156	.069	.626	.487	.504	.209	0.749
.148	.069	.591	.487	[1]	[1]	[1]
.156	.069	.731	.574	.582	.226	.801
.156	.069	.757	.609	.609	.226	.....
.174	.078	.835	.661	.661	.243	.836
.156	.069	.870	.661	.661	.261	.905
.156	.069	.661	.556	.591	.209	.731
.156	.069	.661	.556	.582	235	.818

[1] Not measureable.

Antennæ—Continued.

Cornicles.	Cauda.	Number sensoria on segment III.	Cornicles.	Cauda.	Number sensoria on segment III.
Mm.	*Mm.*		*Mm.*	*Mm.*	
0.556	0.348	13	0.697	.....	12
.556	.....	16	.749	0.383	14
.574	.313	12	.749	.....	12
.591	.....	13	.678	.400	14
.697	.417	15	.697	.....	11

COMPARISON WITH THE EUROPEAN PISI.

After carefully comparing what is commonly known as *Macrosiphum destructor* or *M. pisi* in America with specimens labeled *pisi*, or its equivalent, from Russia, Sweden, England, and Italy, kindly sent us by Cholodkovsky, Mordwilko, Tullgren, Theobald, and Del Guercio, respectively, and with the complete descriptions of Mordwilko (10) and others, we can find no substantial difference and must conclude that the species occurring in Europe and America are identical. Measurements of European specimens of the wingless and winged viviparous, and wingless oviparous females, all taken from specimens mounted on slides in balsam, are given in Table I.

TABLE I.—*Measurements of European specimens of Macrosiphum pisi Kalt.*

WINGLESS VIVIPAROUS FEMALE.

Labeled—	Antennæ.								Length.		Wings.	
	I.	II.	III.	IV.	V.	VI. Base.	VI. Filament.	Number of sensoria on segment III.	Cornicles.	Cauda.	Length.	Width.
	Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*		*Mm.*	*Mm.*	*Mm.*	*Mm.*
Macrosiphum pisi Kalt. Wye, Kent, England, on peas 26-8-'11. F. V. Theobald	0.226	0.122	1.165	0.895	0.817	0.313	1.217	2	0.852	0.748	.....	.....
	.226	.122	1.165	.939	.835	.304	.....	2	.817			
Siphonophora ulmariæ (=S. pisi Kalt.) Firenze, Italy, on Pisum sativum 8-6-1908. G. Del Guercio.	.....	.....	1.234	1.009	.835	.278	1.148	5	1.130	.713	.....	.....
	.....	.....	.....	.....	.....	.....	.....	.....	1.130			
Do	.191	.104	1.304	.....	.....	.....	.....	2	1.199	.739	.....	.....
	.....	.....	.....	.....	.....	.....	.....	.....	1.173			
Do	.243	.122	1.330	1.078	.878	.348	.....	2	1.338	.782	.....	.....
	.226	.122	1.330	1.095	.869	.348	[1] 1.304	3	.....			
Do	.....	.....	[2]	[2]	[2]	.330	[1] 1.304	4	1.078	.696	.....	.....
	.....	.....	1.286	1.086	.887	.313	1.338	3	1.113			
Macrosiphum ulmariæ (=M. pisi Kalt.). On Pisum arvense. Sweden. A. Tullgren	.226	.113	1.356	1.069	.878	.330	[1] 1.200	3	1.200	.800	.....	.....
	.226	.113	1.373	1.095	.921	.....	.....	5	.....			
Siphonophora pisi Kalt. Pisum sativum, Esthland (Russia). N. Cholodkovsky	.....	.....	1.130	.939	.869	.304	1.156	3	1.252	.765	.....	.....
	.....	.....	1.208	.948	.869	.330	1.182	3	1.252			
Macrosiphum pisi Kalt. On Pisum sativum 1/14 VIII '09. Gouvern, Pskow, Russia. A. Mordwilko. Received from N. Cholodkovsky	.....	.....	1.165	.835	.800	.313	1.043	3	.835	.....	.....	.....
	.....	.....	1.148	.800	.800	.296	1.043	2	.835			
Do	.226	.122	1.286	1.078	.965	.313	1.321	3	.974	.783	.....	.....
	.209	.113	1.252	1.043	.974	.313	1.286	3	.974			

[1] Tip shriveled.

[2] Measurements of segments III, IV, and V combined, 3.355 mm.

TABLE I.—*Measurements of European specimens of Macrosiphum pisi Kalt*—Contd.

WINGED VIVIPAROUS FEMALE.

Labeled—	Antennæ.								Length.		Wings.	
	I.	II.	III.	IV.	V.	VI. Base.	VI. Filament.	Number of sensoria on segment III.	Cornicles.	Cauda.	Length.	Width.
	Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*		*Mm.*	*Mm.*	*Mm.*	*Mm.*
Macrosiphum pisi Kalt. On sweet peas 20-9-'12. England. F. V. Theobald	0.191	0.113	1.069	0.930	0.843	0.313	1.182	29	0.748	0.539	4.41	1.62
	.191	.113	1.060	.913	.852	.330	1.182	25	.765			
Macrosiphum ulmariæ (=pisi Kalt). On Pisum arvense. Sweden. A. Tullgren	.208	.113	1.148	.991	.817	.321	.....	21	.956	.608	.....	.....
	.208	.113	1.113	.....	.....	.....	.....	21	.904			
Macrosiphum pisi Kalt. On Pisum sativum, 1/14 VIII '09. Gouvern, Pskow, Russia. A. Mordwilko. Rec'd from N. Cholodkovsky	.208	.104	1.061	.913	.817	.313	1.304	22	1.008	.608	4.45	1.55
	.208	.096	1.078	.965	.817	.330	1.278	26	.991			
Macrosiphum pisi Kalt. On Lathyrus sp., Oct., 1903. Warschau, Russia. A. Mordwilko. Rec'd from N. Cholodkovsky	.174	.104	[1]1.061	1.095	.904	.330	[2]1.061	26	.782	.556	.....	.....
	.....	.....	.....	.....	.....	.....	.....	.....	.800			

WINGLESS OVIPAROUS FEMALE.

Macrosiphum pisi Kalt. On Lathyrus sp., Oct., 1903. Warschau, Russia. A. Mordwilko. Rec'd from N. Cholodkovsky	0.191	0.104	0.982	0.721	0.765	0.295	1.043	2	0.713	.....	.....	.....
	.191	.104	.956	.730	.756	.269	1.043	2	.....			
Do	.191	.113	1.113	.782	.748	.313	1.061	2	.800	.....	.....	.....
	.191	.104	1.130	.765	.748	.295	1.061	4	.....			

[1] Upturned, and measurements only approximate.

In no case, in specimens included in this table, were sensoria present on antennal segments IV and V, excepting the usual distal one on V; the cornicles were imbricated throughout, there being no reticulation at the tips. The hind tibiæ of the oviparous females bore numerous sensoria as is the case with specimens occurring in America. Figure 10, *a–d* were made from specimens collected by Dr. A. Mordwilko in Russia and sent us by Dr. N. Cholodkovsky.

We have not had an opportunity to examine specimens of the wingless or winged males from Europe but our specimens of the wingless male agree in every particular with the description given by Mordwilko (10).

LIFE HISTORY.

The life history of the pea aphis is quite simple, for it does not have a true alternate host like some species of plant-lice. As has been noted, it attacks leguminous plants primarily, some of which are annuals, others perennials. Clovers, particularly red and crimson clovers, serve as hosts for this insect the entire year, and it is on these plants that it usually passes the winter, either as eggs or as viviparous females, although during the summer months the migrants also pass to other leguminous crops, such as sweet pea, garden and field peas, and vetches, and on these they multiply very rapidly, oftentimes destroying large acreages. In the latitude of La Fayette, Ind., the species winters both as living viviparous females, usually wingless, and as eggs. Farther north it may winter exclusively in the egg stage, although our observations are not complete on this point,

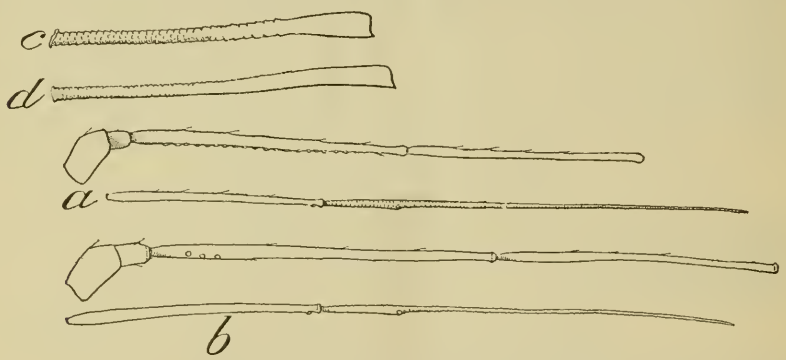

FIG. 10.—*Macrosiphum pisi* from Russia: *a*, antenna of winged viviparous female; *b*, antenna of wingless viviparous female; *c*, cornicle of winged viviparous female; *d*, cornicle of wingless viviparous female. Greatly enlarged. (Original.)

while farther south, in the latitude of Tennessee, the sexual forms which lay the overwintering eggs are rare, the insect ordinarily passing the winter as living plant-lice, both wingless and winged forms being able to withstand the lower temperatures in that latitude. Still farther south we know only the viviparous females and our observations lead us to believe that the species may reproduce viviparously indefinitely in localities where the winters are quite mild.

FIELD OBSERVATIONS.

In the latitude of Illinois, Indiana, Maryland, and Delaware migrants from the winter hosts, namely, red clover and crimson clovers, begin to spread to new fields of clover and to garden peas about May 1, and the injury to these crops usually becomes noticeable about June 1, extending up to July. Ordinarily by this time the parasitic and predacious enemies have become sufficiently numerous

to control, or at least hold in check, the aphides, and a little later, usually depending on the climatic conditions, the aphidid fungus (*Empusa aphidis*) becomes prevalent, so much so, in fact, that the plant-lice are often apparently completely exterminated. However, as the weather conditions become more favorable for the aphis and less for the fungous disease and the aphidid parasites, the few survivors are soon able to cover the plants with their progeny, so that by September we ordinarily find them again abundant on clover and late garden peas.

Farther north the insect does not seem to appear in injurious numbers until later—that is, not until about July. The following records of injury for 1899 recorded by Dr. Chittenden (1900) illustrate this statement. The first record was for Gloucester County and Portsmouth, Va., on May 17; Maryland, May 23; Newark, Del., June 2; East Hampton, Conn., July 3; Long Island, N. Y., July 7: Orono, Me., July 28; Ontario and Nova Scotia, Canada, August 9.

GENERATION EXPERIMENTS.

We have carried on generation experiments with this species through two years (1912 and 1913) at La Fayette, Ind., and the following notes were made at La Fayette, except as indicated. The same general methods, as well as the cages and rearing shelters, heretofore used by the writer and described and figured in Technical Series Bulletin No. 25, Part II, of the Bureau of Entomology, have been adopted. The writer here expresses his appreciation of the services rendered by Messrs, C. W. Creel and A. F. Satterthwait, both of the Cereal and Forage Crop Insect Investigations, who attentively cared for the experiments during the absences of the writer in 1912 and 1913, respectively.

In 1913 eggs began to hatch on March 31 and from that date until January, 1914, there was obtained, out of doors, a maximum of 19 generations, no sexual forms being produced in the first-born generation series. On the other hand, following down "the last-born of the last-born" generation series, a minimum of 7 generations was obtained, the last generation consisting of males. The last generation, in this case, was really the twelfth generation from the egg, for a break in the first series of last-born generations made it necessary to substitute with the last-born of a later generation. Thus we obtained an average of 13 generations for the year. (See Table II.)

TABLE II.—*First and last generation series of Macrosiphum pisi from egg, March 31, 1913, La Fayette, Ind.*

Date.	Temperature.[1]		First-born generation series.																			Last-born generation series.									
	Maximum.	Minimum.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.	Eleventh generation.	Twelfth generation.	Thirteenth generation.	Fourteenth generation.	Fifteenth generation.	Sixteenth generation.	Seventeenth generation.	Eighteenth generation.	Nineteenth generation.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.	Eleventh generation.	Twelfth generation.
1913.	° F.	° F.																														
Mar. 31	56	?	a																													
Apr. 1	64	34	0																													
Apr. 2	75	45	0																													
Apr. 3	74	60	0																													
Apr. 4	62	41	0																													
Apr. 5	56	33	0																													
Apr. 6	55	29	0																													
Apr. 7	48	32	0																													
Apr. 8	47	33	0																													
Apr. 9	48	39	0																													
Apr. 10	61	46	0																													
Apr. 11	46	41	0																													
Apr. 12	41	37	0																													
Apr. 13	54	37	0																													
Apr. 14	62	35	0																													
Apr. 15	67	35	0																													
Apr. 16	71	30	0																													
Apr. 17	79	46	0																													
Apr. 18	80	48	0																													
Apr. 19	68	42	0																													
Apr. 20	66	35	0																													
Apr. 21	72	38	0																													
Apr. 22	83	47	0																													
Apr. 23	81	58	0																													
Apr. 24	81	61	2	b																												
Apr. 25	77	49	6	0																												
Apr. 26	56	44	1	0																												
Apr. 27	64	32	1	0																												
Apr. 28	53	40	0	0																												
Apr. 29	76	38	4	0																												
Apr. 30	83	43	3	0																												
May 1	90	48	6	0																												
May 2	89	53	6	0																												
May 3	87	58	8	0																												
May 4	82	62	4	0																												
May 5	83	63	7	0																												
May 6	84	54	5	0																												

| | | |

TABLE II.—*First and last generation series of Macrosiphum pisi from egg, March 31, 1913, La Fayette, Ind.*—Continued.

Date.	Temperature.		First-born generation series.																			Last-born generation series.										
	Maximum.	Minimum.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.	Eleventh generation.	Twelfth generation.	Thirteenth generation.	Fourteenth generation.	Fifteenth generation.	Sixteenth generation.	Seventeenth generation.	Eighteenth generation.	Nineteenth generation.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.	Eleventh generation.	Twelfth generation.
1913.	° F.	° F.																														
June 20	101	66	....	....	0	2	2	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3									
June 21	95	70	....	....	0	3	4	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4									
June 22	84	62	....	....	0	0	5	4	b	....	....	....	....	....	....	....	....	....	....	....	....	....	1									
June 23	75	63	....	....	0	1	2	5	0	....	....	....	....	....	....	....	....	....	....	....	....	....	1									
June 24	81	(?)	....	....	0	0	3	7	0	....	....	....	....	....	....	....	....	....	....	....	....	....	1									
June 25	83	72	....	....	0	0	3	5	0	....	....	....	....	....	....	....	....	....	....	....	....	....	6									
June 26	86	69	....	....	0	0	4	9	0	....	....	....	....	....	....	....	....	....	....	....	....	....	0									
June 27	93	71	....	....	0	0	2	4	0	....	....	....	....	....	....	....	....	....	....	....	....	....	0									
June 28	94	75	....	....	0	0	1	6	0	....	....	....	....	....	....	....	....	....	....	....	....	....	2	b								
					90	111																										
June 29	95	74	....	....	....	....	0	5	0	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0								
																							92									
June 30	94	76	....	....	....	....	0	6	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0								
July 1	94	75	....	....	....	....	2	6	4	b	....	....	....	....	....	....	....	....	....	....	....	....	....	0								
July 2	90	71	....	....	....	....	3	2	6	0	....	....	....	....	....	....	....	....	....	....	....	....	....	0								
July 3	90	73	....	....	....	....	3	4	4	0	....	....	....	....	....	....	....	....	....	....	....	....	....	0								
July 4	92	74	....	....	....	....	0	2	2	0	....	....	....	....	....	....	....	....	....	....	....	....	....	0								
July 5	93	74	....	....	....	....	0	3	5	0	....	....	....	....	....	....	....	....	....	....	....	....	....	0								
July 6	95	66	....	....	....	....	0	0	3	0	....	....	....	....	....	....	....	....	....	....	....	....	....	0								
							59																									
July 7	84	60	....	....	....	....	....	0	3	0	....	....	....	....	....	....	....	....	....	....	....	....	....	0								
								68																								
July 8	92	65	....	....	....	....	....	....	1	0	....	....	....	....	....	....	....	....	....	....	....	....	....	0								
July 9	94	66	....	....	....	....	....	....	1	0	....	....	....	....	....	....	....	....	....	....	....	....	....	0								
July 10	90	61	....	....	....	....	....	....	3	0	....	....	....	....	....	....	....	....	....	....	....	....	....	0								
July 11	85	57	....	....	....	....	....	....	3	0	....	....	....	....	....	....	....	....	....	....	....	....	....	0								
July 12	89	70	....	....	....	....	....	....	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	0								
July 13	88	63	....	....	....	....	....	....	3	0	....	....	....	....	....	....	....	....	....	....	....	....	....	0								
July 14	90	67	....	....	....	....	....	....	1	0	....	....	....	....	....	....	....	....	....	....	....	....	....	0								
July 15	94	70	....	....	....	....	....	....	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	0								
July 16	92	76	....	....	....	....	....	....	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	0								

| | | |

TABLE II.—*First and last generation series of Macrosiphum pisi from egg, March 31, 1913, La Fayette, Ind.*—Continued.

Date.	Temperature.		First-born generation series.																		Last-born generation series.											
	Maximum.	Minimum.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.	Eleventh generation.	Twelfth generation.	Thirteenth generation.	Fourteenth generation.	Fifteenth generation.	Sixteenth generation.	Seventeenth generation.	Eighteenth generation.	Nineteenth generation.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.	Eleventh generation.	Twelfth generation.
1913.	° F.	° F.																														
Aug. 27	92	69											3	5	0																10	
Aug. 28	94	66											1	4	0																3	
Aug. 29	94	53											4	3	0																9	
Aug. 30	78	53											0	4	0																2	
Aug. 31	82	62											2	3	0																6	
Sept. 1	83	69											6	5	0																6	
Sept. 2	97	67											0	2	0																7	
Sept. 3	98	68											0	4	8	b															3	
Sept. 4	98	69											0	3	7	0															4	
Sept. 5	86	64											0	2	5	0															4	
Sept. 6	91	70											0	7	5	0															5	
Sept. 7	95	71											0	2	8	0															6	
Sept. 8	92	64											0	1	3	0															3	
													70																			
Sept. 9	96	53												1	3	0															1	
Sept. 10	79	50												0	2	1															1	
Sept. 11	85	57												2	6	5	b														1	
Sept. 12	90	61												1	2	5	0														0	
Sept. 13	71	52												0	3	2	0														0	
Sept. 14	70	48												0	5	1	0														0	
Sept. 15	72	50												0	3	5	0														1	b
Sept. 16	69	50												0	2	2	0														0	0
Sept. 17	76	67												0	4	2	0														0	0
Sept. 18	73	58												0	2	4															0	0
																27															75	
Sept. 19	73	52												0	3		0															0
Sept. 20	70	55												0	2		0															0
Sept. 21	55	45												0	0		0															0
Sept. 22	50	42												0	0		0															0
Sept. 23	52	37												0	0		1	b														0
Sept. 24	76	54												0	0		7	0														0
Sept. 25	82	52												0	0		5	0														0
Sept. 26	81	51												0	0		6	0														0
Sept. 27	58	38												0	0		1	0														0
														57																		

| | | |

TABLE II.—*First and last generation series of Macrosiphum pisi from egg, March 31, 1913, La Fayette, Ind.*—Continued.

Date.	Temperature.		First-born generation series.																		Last-born generation series.											
	Maximum.	Minimum.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.	Eleventh generation.	Twelfth generation.	Thirteenth generation.	Fourteenth generation.	Fifteenth generation.	Sixteenth generation.	Seventeenth generation.	Eighteenth generation.	Nineteenth generation.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.	Eleventh generation.	Twelfth generation.
1913.	° F.	° F.																														
Nov. 16	42	38	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	2	10	0												
Nov. 17	52	38	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0			0												
Nov. 18	64	47	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0			0												
																	104															
Nov. 19	64	58	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....			0												
Nov. 20	67	58	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	7	6	0												
Nov. 21	68	56	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3	0	0												
Nov. 22	71	60	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	2	0												
Nov. 23	77	42	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0													
Nov. 24	49	34	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	3	b											
Nov. 25	65	33	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0													
Nov. 26	50	42	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	4	0											
Nov. 27	51	46	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	2	0											
Nov. 28	57	48	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0													
Nov. 29	57	55	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	3	0											
Nov. 30	59	55	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0			0											
Dec. 1	59	51	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	1	4	0											
Dec. 2	60	52	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0			0											
Dec. 3	56	50	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	7	0											
Dec. 4	51	38	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0			0											
																		96	3	4	0											
Dec. 5	50	37	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....				0											
Dec. 6	58	41	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....				0											
Dec. 7	56	32	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....		2	1												
Dec. 8	32	19	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....		0	1	0											
Dec. 9	39	29	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....		0	0	0											
Dec. 10	47	32	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....		0	0	0											
Dec. 11	47	26	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....		0	0	0											
Dec. 12	52	29	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....		0	0	0											
Dec. 13	54	30	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....		2	0	0											
Dec. 14	56	32	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....			0	0											

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TABLE III.—*First and last generation series from an individual Macrosiphum pisi collected in the field May 15, 1912, La Fayette, Ind.*

Date.	Temperature.[1]		First-born generation series.																Last-born generation series.							
	Maximum.	Minimum.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.	Eleventh generation.	Twelfth generation.	Thirteenth generation.	Fourteenth generation.	Fifteenth generation.	Sixteenth generation.	Seventeenth generation.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.
1912.	°F.	°F.																									
May 15	65	46½	a																								
May 16	56	47½	0																								
May 17	67½	47	0																								
May 18	72	45½	0																								
May 19	73+	61	0																								
May 20	82½	-----	0																								
May 21	84	64	0																								
May 22	86	62	0																								
May 23	87½	67½	0																								
May 24	82	67	12																								
May 25	78½	60																									
May 26	83	56	10																								
May 27	89	66																									
May 28	81½	63	2																								
May 29	74	51	2	b																							
May 30	62	49																									
May 31	78	53	3	0																							
June 1	85	57½		0																							
June 2	87	61	9	0																							
June 3	77½	55		0																							
June 4	80	58		0																							
June 5	79	52	6	0																							
June 6	82	63		0																							
June 7	71	48		0																							
June 8	71	44	4	0																							
June 9	83	46		0																							
June 10	76½	53	4	0																							
June 11	81	55	5	7	b																						
June 12	85	58		4	0																						
June 13	80	56½	2	1	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	----	b						
June 14	78	61	0	5	0	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	----	0						
			59																								

| | | |

TABLE III.—*First and last generation series from an individual Macrosiphum pisi collected in the field May 15, 1912, La Fayette, Ind.*—Continued.

Date.	Temperature.		First-born generation series.																Last-born generation series.							
	Maximum.	Minimum.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.	Eleventh generation.	Twelfth generation.	Thirteenth generation.	Fourteenth generation.	Fifteenth generation.	Sixteenth generation.	Seventeenth generation.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation
1912	°F.	°F.																									
July 21	91	76							8	0												7					
July 25	93	71							6	0												5					
									17																		
July 26	86½	61								0												4					
July 27	78	57								0												4					
July 28	81	63								0												4					
July 29	79½	66								0												4					
July 30	81	59								0												3					
July 31	81	61								0												2					
Aug. 1	71	52								0												3					
Aug. 2	74½	56								5	b											4					
Aug. 3	73	50								3	0											1					
Aug. 4	71	49								3	0											1					
Aug. 5	72	47								3	0											1					
Aug. 6	76	60½								7	0											1					
Aug. 7	81	65½								6	0											0					
Aug. 8	75	67½								6	0											3					
Aug. 9	81	69								5	0											2	b				
Aug. 10	73	61								0	0											0	0				
Aug. 11	76	63½								4	6	b										0	0				
Aug. 12	81	59								7	9	0										0	0				
Aug. 13	82	68								1	12	0										0	0				
Aug. 14	86	66								2	12	0										0	0				
																						63					
Aug. 15	88½	62								5	8	0											0				
Aug. 16	84	62								2	9	0											0				
Aug. 17	87	65								1	12	0											0				
Aug. 18	91½	70								3	8	2	b										8				
Aug. 19	91	70								3	4	8	0										6				
Aug. 20	99½	69								2	5	11	0										4				
Aug. 21	85	68								3	3	9	0										5				
											88																

| | | |

TABLE III.—*First and last generation series from an individual Macrosiphum pisi collected in the field May 15, 1912, La Fayette, Ind.*—Continued.

Date.	Temperature.		First-born generation series.																Last-born generation series.							
	Maximum.	Minimum.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.	Eleventh generation.	Twelfth generation.	Thirteenth generation.	Fourteenth generation.	Fifteenth generation.	Sixteenth generation.	Seventeenth generation.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.
1912.	°F.	°F.																									
Sept. 30	77	33														1	0									0	
Oct. 1	75	44														1	0									0	
Oct. 2	79½	39														0	0									0	
Oct. 3	80½	47½														3	0									0	
Oct. 4	72	44														5	0									0	
Oct. 5	79	46														3	0									0	
Oct. 6	84½	59														3	0									0	
Oct. 7	85½	52														2	0									0	
Oct. 8	59	41														3	0									0	
Oct. 9	68	45														4	0									0	
Oct. 10	76½	63														4	1									0	
Oct. 11	67	51														3	8	b								0	
Oct. 12	82	39														3	10	0								0	
																50											
Oct. 13	58½	35															2	0								0	
Oct. 14	64	38															1	0								5	
Oct. 15	63	38															2	0								3	
Oct. 16	66½	41															7	0								3	
Oct. 17	71	49																0								2	
Oct. 18	74	42															7	0								8	
Oct. 19	65½	37															3	0								1	
Oct. 20	59	41															1	0								2	
Oct. 21	66	52															5	0								4	
Oct. 22	78	41															7	0								5	
Oct. 23	57	32															1	0								0	
Oct. 24	51	32															1	0								1	
Oct. 25	58	34															2	0								2	
Oct. 26	65	38															3	0								2	
Oct. 27	66	45															1	0								1	
Oct. 28	72	45															3	0								1	
Oct. 29	73	50															6	0								9	
Oct. 30	74	36															3									0	
Oct. 31	58	38															1	8	b							4	
Nov. 1	45	36															1									1	

| | | |

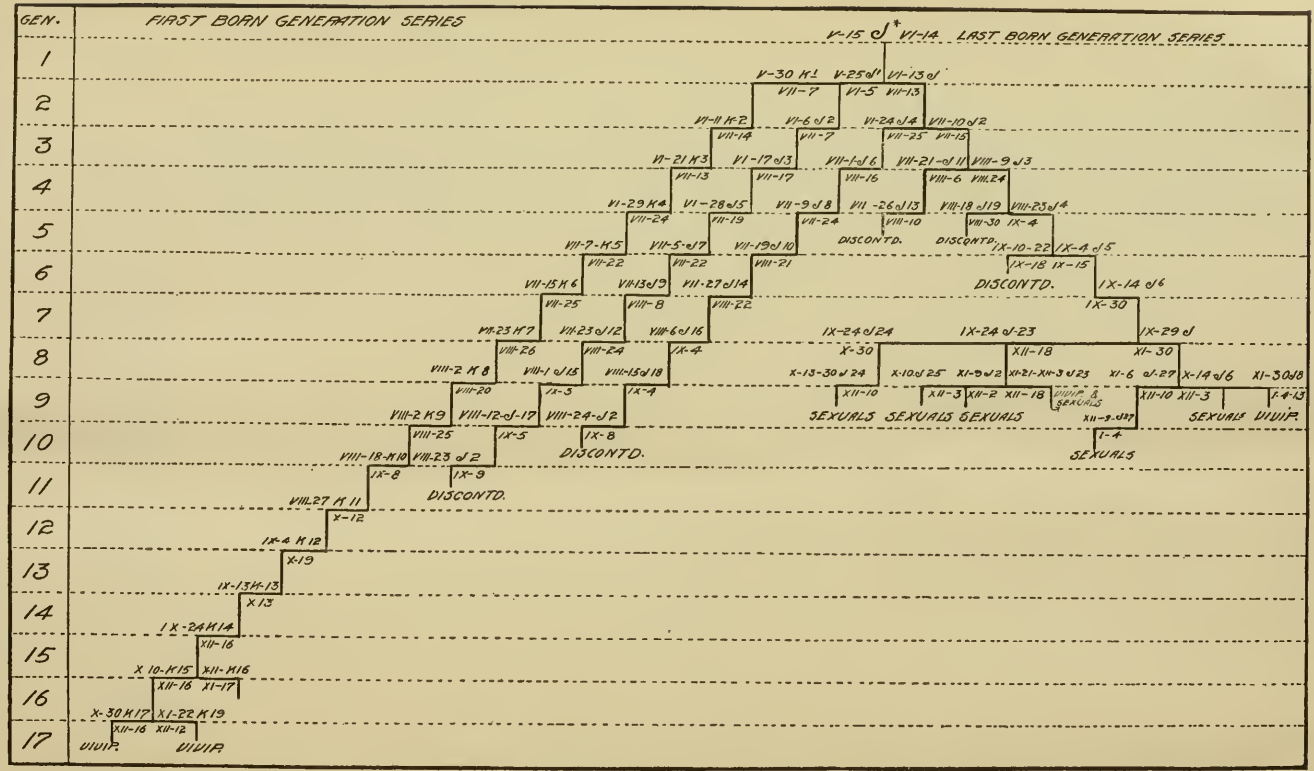

FIG. 11.—Graphic illustration of line of generations of *Macrosiphum pisi* in 1912 and individual cages, all the progeny of one mother. (Original.)

[* Immature individuals (probably second generation from egg) collected in the field May 15, 1912. Roman numerals indicate month, followed by day and cage number. Figures above line, date of birth and cage number; below line, date of death.]

Figure 11 shows graphically the lines of generations carried through in 1912 and the different individual experiments in each generation, including the cage number and dates of birth above the line and the date of death or termination of the experiment below the line, for each cage record. Figure 12 shows the length of each generation of the same series (1912).

Thus it will be noticed that the first generation in the series (probably the second generation from the egg) was the shortest, while the ninth generation was the longest, extending over a period of 156 days. Likewise it will be seen that on June 1 two generations coexisted; on July 1, four generations, from the second to the third; on August 1, seven generations, from the third to the ninth, inclusive, and on September 1, eight generations, from the fifth to the twelfth.

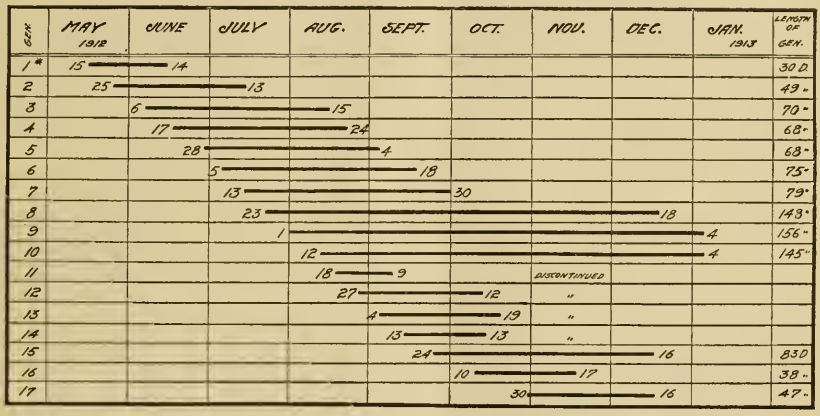

FIG. 12.—Periods and succession of generations in *Macrosiphum pisi*, La Fayette, Ind., 1912.

* This is the first generation found in the field and is probably about the third from the egg.

HATCHING OF THE EGG.

At La Fayette, Ind., the eggs of *M. pisi* hatch the latter part of March; in the cases recorded in 1913 they hatched March 31. Folsom (1909) records the hatching of eggs at Urbana, Ill., March 23, in 1905.

MOLTING.

According to our experiments this plant louse, like others of this family of insects, has five instars and never molts more than four times. In 1905 Mr. R. L. Webster, then an assistant of Dr. S. A. Forbes, State entomologist of Illinois, observed 10 individuals, all of which molted four times, although Mr. J. P. Gilbert, at the same laboratory, claims to have observed an individual molt five times (Folsom, 1909). Table IV gives our detailed records.

TABLE IV.—*Records of molts of Macrosiphum pisi. La Fayette, Ind., 1912.*

	Date of first molt.	Period between birth and first molt.	Date of second molt.	Period between first and second molts.	Date of third molt.	Period between second and third molts.
1911.		*Hours.*		*Hours.*		*Hours.*
11.00 a. m., Aug. 14.	7.30 p. m., Aug. 15..	32½	11.30 a. m., Aug 17.	40	Died	
1.00 p. m., Aug. 14..	5.30 a. m., Aug. 16..	40½	1.30 p. m., Aug. 17..	32	.....do	
11.00 a. m., Aug. 14.	8.00 a. m., Aug. 16..	45	Died			
3.30 p. m., Aug. 14..	5.30 a. m., Aug. 16..	38	7.00 p. m., Aug. 17..	37½	5.30 a. m., Aug. 19.	34½
3.00 p. m., Aug. 14..	5.30 a. m., Aug. 16..	38½	4.30 p. m., Aug. 17..	35	5.30 a. m., Aug. 19.	37
4.30 p. m., Aug. 14..	12.00 m., Aug. 16....	43½	5.30 p. m., Aug. 17..	29½	5.30 a. m., Aug. 19.	48
4.30 p. m., Aug. 14..	12.00 m., Aug. 16....	43½	9.00 a. m., Aug. 18..	45	5.30 a. m., Aug. 20.	44½
6.00 p. m., Aug. 14..	12.00 m., Aug. 16....	42	7.00 p. m., Aug. 17..	31	5.30 a. m., Aug. 19.	31½
9.00 a. m., Aug. 15..	5.15 a. m., Aug. 17..	44¼	5.30 a. m., Aug. 18..	24¼	11.30 a. m., Aug. 19	30
9.45 a. m., Aug. 15[1].	5.15 a. m., Aug. 17..	43½	6.30 a. m., Aug. 18..	25¼	2.30 p. m., Aug. 19.	32
10.00 a. m., Aug. 15.	5.15 a. m., Aug. 17..	43¾	5.30 a. m., Aug. 18..	24¼	2.30 p. m., Aug. 19.	33
10.15 a. m., Aug. 15.	6.00 a. m., Aug. 17..	43¾	9.00 a. m., Aug. 18..	27	3.30 p. m., Aug. 19.	30½
4.30 p. m., Aug. 18..	1.00 p. m., Aug. 20..	44½	11.45 a. m., Aug. 22.	46¾	3.30 p. m., Aug. 24.	51¾
4.30 p.m., Aug. 18...	5.30 a. m., Aug. 20..	37	4.45p. m., Aug. 22..	59¼	5.30 p. m., Aug. 25.	72¾
5.00 p. m., Aug. 18..	10.00 a. m., Aug. 20.	41	7.15 a. m., Aug. 23..	69¼	Died	
10.00 a. m., Aug. 19.	7.45 p. m., Aug.20...	33¾	6.15 a. m., Aug. 22..	34½	5.15 a. m., Aug. 24.	47
10.00 a. m., Aug. 19.	5.30 a. m., Aug. 21..	43½	5.45 p. m., Aug. 22..	36½	7.30 a. m., Aug. 24.	37¾
1.00 p. m., Aug. 22..	9.45 a. m., Aug. 24..	44¾	5.30 a. m., Aug. 25..	19¾	Aug. 27	
1913.		*Days.*		*Days.*		*Days.*
Apr. 3[2]	Apr. 4	1	Apr. 7	3	Apr. 9	2
Apr. 2[2]	Apr. 4	2	Apr. 7	3		
Mar. 31[3]	Apr. 5	5	Apr. 16	11	Apr. 19	3

	Date of fourth molt.	Period between third and fourth molts.	Date of first young.	Period between fourth molt and birth of first young.	Entire immature period (approximate).
1912.		*Hours.*		*Hours.*	*Days.*
11.00 a. m., Aug. 14					
1.00 p. m., Aug. 14					
11.00 a. m., Aug. 14					
3.30 p. m., Aug. 14	Removed for description.				
3.00 p. m., Aug. 14	5.30 a. m., Aug. 21	48	5.15 a. m., Aug. 22	23¾	7½
4.30 p. m., Aug. 14	5.00 p. m., Aug. 20	23½	5.15 a. m., Aug. 22	36¼	7½
4.30 p. m., Aug. 14	1.00 p. m., Aug. 22	31½	6.00 a. m., Aug. 23	17	7½
6.00 p. m., Aug. 14	7.45 p. m., Aug. 20	38¼	5.15 a. m., Aug. 22	33½	7½
9.00 a. m., Aug. 15	5.30 a. m., Aug. 21	42	1.00 p. m., Aug. 22	31½	7⅛
9.45 a. m., Aug. 15	8.00 a. m., Aug. 22	65½	6.00 p. m., Aug. 24	58	9½
10.00 a. m., Aug. 15	1.00 p. m., Aug. 21	46½	1.00 p. m., Aug. 23	48	8⅛
10.15 a. m., Aug. 15	1.45 p. m., Aug. 21	46¼	4.00 p. m., Aug. 23	50¼	8¼
4.30 p. m., Aug. 18	2.15 p. m., Aug. 26	46¾	Aug. 28		9+
4.30 p. m., Aug. 18	Died				
5.00 p. m., Aug. 18					
10.00 a. m., Aug. 19	Removed for description.				
10.00 a. m., Aug. 19	8.15 a. m., Aug. 26	48¾			8+
1.00 p. m., Aug. 22	Aug. 29		Aug. 30		8
1913.		*Days.*			
Apr. 3[2]	Apr. 11	2	Apr. 14		11
Apr. 2[2]	Apr. 14		Apr. 17		15
Mar. 31[3]	Apr. 23	4	Apr. 24		24

[1] Winged female; all others wingless.
[2] Records by Gibson at Nashville, Tenn., in 1913.
[3] Hatched from egg.

It will be observed that only one record of a winged female was noted, and this individual required a noticeably longer time to reach maturity than did the wingless forms observed at the same time. This has been our observation time and again, although no definite records were kept.

AGE AT WHICH FEMALES BEGIN REPRODUCING.

In 1912 the age at which females began giving birth to young varied from 6 to 35 days, with an average of 10.3 days, from 38 records covering the months from May 15 to December. (Table V.)

TABLE V.—*Line of generations of Macrosiphum pisi from May 15, La Fayette, Ind., 1912.*

Cage number.	Generation.	Date of birth.	Date of first young.	Age at birth of first young.	Date of last young.	Reproductive period.	Life after last young.	Number of young.	Average young per day of productive period.	Largest number of young in one day.	Date of death or disappearance.	Total length of life.
First-born generation series:		1912.		*Days.*		*Days.*	*Days.*					*Days.*
J	[1] 1	May 15 [1]	May 24-25		June 13	20 or 21	1	59	2.8+ to 2.9+	5	June 14	
K1	2	May 30	June 11	12	July 5	25	2	60	2.4	5	July 7	38
K2	3	June 11	June 21	10	July 8	18	6	92	5.1+	10	July 14	33
K3	4	June 21	June 29	8	July 12	13	1	99	7.6+	14	July 13	21
K4	5	June 29	July 7	8	July 22	16	2	84	5.2+	10	July 24	25
K5	6	July 7	July 15	8	...do	8		50	6.2+	11	July 22	15
K6	7	July 15	July 23	8	July 25	3		17	5.6+	8	July 25 [2]	10
K7	8	July 23	Aug. 2	10	Aug. 22	21	4	72	3.4+	7	Aug. 26	34
K8	9	Aug. 2	Aug. 11	9	Aug. 20	10		88	8.8	12	Aug. 2 [3]	18
K9	10	Aug. 11	Aug. 18	7	Aug. 22	5	3	38	7.6	11	Aug. 25 [3]	14
K10	11	Aug. 18	Aug. 27	9	Sept. 8	13		69	5.3+	9	Sept. 8	21
K11	12	Aug. 27	Sept. 4	8	[4]							
K12	13	Sept. 4	Sept. 10	6	[4]							
K13	14	Sept. 13	Sept. 24	11	Oct. 12	19	1	50	2.6+	5	Oct. 13 [3]	30
K14	15	Sept. 24	Oct. 10	16	Dec. 5	57	11	102	1.8—	10	Dec. 16	83
K15	16	Oct. 10 or 11	Oct. 30	19 or 20	...do	37	11	58	1.6—	7	...do	66 to 67
K17	17	Oct. 30 or 31	Dec. 4 [5]	35	...do	2		6	3.0		Dec. 16-20 [6]	47 to 51
Last-born generation series:												
J1	2	June 13	June 24	11	July 10	17	3	54	3.2—	8	July 13	30
J2	3	July 10	July 21	11	Aug. 9	20	6	63	3.1+	7	Aug. 15	36
J3	4	Aug. 9	Aug. 18	9	Aug. 21	7		33	4.7+	8	Aug. 24	15
J4	5	Aug. 24	Sept. 1	8	Sept. 4	4		14	3.5	5	Sept. 4 [3]	11
J5	6	Sept. 4	Sept. 11	7	Sept. 14 [3]	4	1	10	2.5	5	Sept. 15 [3]	11
J6	7	Sept. 14	Sept. 24	10	Nov. 30	68		80	1.2—	9	Nov. 30	77
J7	8	Nov. 30	[7]									
Additional miscellaneous generation series:												
J1	2	May 24-25	June 6	12 or 13	June 28	23	7	41	1.8—	5	July 5	41 or 42
J2	3	June 6	June 17	11	July 4	18	3	69	3.8+	6	July 7	31
J3	4	June 17	June 28	11	July 14	17	3	106	6.2+	12	July 17	30
J4	3	June 24	July 1	7	July 18	18	7	119	6.6+	13	July 25	31
J5	5	June 28	July 5	7	July 19	15		94	6.3—	9	July 19	21
J6	4	July 1	July 9	8	July 15	7		41	5.9—	10	July 15	14
J7	6	July 5	July 13	8	July 21	9	1	37	4.1+	6	July 22 [3]	17
J9	7	July 13	July 23	10	Aug. 7	16	1	33	2.1—	4	Aug. 8 [3]	23
J10	6	July 19	July 27	8	Aug. 20	25	1	78	3.1+	7	Aug. 21	33
J11	4	July 21	July 26	5	Aug. 5	11	1	42	3.8+	7	Aug. 6	16
J12	8	July 23	Aug. 1	9	Aug. 23	23	1	72	3.1+	7	Aug. 24	32

J14	7	July 27	Aug. 6	10	Aug. 21	16	1	108	6.7+	12	Aug. 22	26
J15	9	Aug. 1	Aug. 12	11	Aug. 29	18	5	53	2.9+	6	Sept. 3	33
J16	8	Aug. 6	Aug. 15	9	Sept. 3	20	1	87	4.3+	10	Sept. 4	29
J18	9	Aug. 15	Aug. 23	8	do	12	1	57	4.7+	11	do	20
J23	8	Sept. 24	Oct. 10	16	Dec. 3	55	15	57	1.0+	9	Dec. 18	85

[1] Immature individuals collected in field; probably second or third generation from egg.
[2] Accidentally killed.
[3] Killed by fungus.
[4] By mistake progeny and life of single individual not kept.
[5] Placed in greenhouse Nov. 27 to hasten maturity. Transferred to outdoor shelter Dec. 4, after one mother had given birth to three young.
[6] Mother and young killed by cold.
[7] All viviparous and killed by cold.

The immature period varied from 7 to 56 days, between April, 1913, and January, 1914, with an average from 22 records of 15.3 days. (Table VI.)

TABLE VI.—*Line of generations of Macrosiphum pisi from stem-mother hatching from egg, La Fayette, Ind., Mar. 31, 1913.*

Cage number.	Generation.	Date of birth.	Date of first young.	Age at birth of first young.	Date of last young.	Reproduction period.	Life after last young.	Number of young.	Average young per day of productive period.	Largest number of young in one day.	Date of death or disappearance.	Total length of life.
First-born generation series:				*Days.*		*Days.*	*Days.*					*Days.*
Pi-1	1	Mar. 31	Apr. 24	24	May 22	29	8	88	3.0+	8	May 30	60
Pi-2	2	Apr. 24	May 7	13	June 2	27	13	124	4.6−	11	June 15	52
Pi-3	3	May 7	May 21	14	June 16	27	13	90	3.3+	7	June 29	53
Pi-4	4	May 21	June 2	12	June 23	22	6	111	5.0+	11	...do	39
Pi-5	5	June 2	June 14	12	July 3	20	4	59	3.0−	5	July 7	35
Pi-6	6	June 14	June 22	8	July 5	14	2	68	4.8+	7	July 8	24
Pi-7	7	June 22	July 1	9	July 14	14	5	39	2.8−	6	July 19	27
Pi-8	8	July 1	July 18	17	Aug. 1	15	3	29	2.0−	4	Aug. 4	34
Pi-9	9	July 18	July 30	12	Aug. 14	16	0	38	2.3+	6	Aug. 14	27
Pi-10	10	July 30	Aug. 7	8	Aug. 8	2	1	5+	2.5	5	Aug. 9	10
Pi-11	11	Aug. 8	Aug. 16	8	Sept. 1	17	8	70	4.1+	8	Sept. 9	32
Pi-12	12	Aug. 16	Aug. 25	9	Sept. 12	19	16	57	3.0	7	Sept. 28	43
Pi-13	13	Aug. 25	Sept. 3	9	Sept. 20	18	11	73	4.0+	8	Oct. 1	37
Pi-14	14	Sept. 3	Sept. 10	7	Sept. 18	9	1	27	3.0	5	Sept. 19	16
Pi-15	15	Sept. 11	Sept. 23	12	Nov. 6	45	9	104	2.3+	7	Nov. 15	65
Pi-16	16	Sept. 23	Oct. 6	13	Nov. 21	47	14	96	2.0+	10	Dec. 5	73
Pi-17	17	Oct. 6	Oct. 16	10	Dec. 15-22	61-68	0	60	1.0−	6	Dec. 22	77
Pi-18	18	Oct. 16	Nov. 22	37	Dec. 8	17	25	29	1.7+	4	Jan. 2[1]	78
Pi-19a	19	Nov. 25-29	Jan. 24[1]	56-60	[2]							
Last-born generation series:												
PiPi-2	2	May 22	June 3	12	June 28	26	2	92	3.5+	7	June 30	39
PiPi-3	3	June 28	[3]									
PiPi-9	9	July 31	Aug. 9	9	Aug. 17	9	1	27	3.0	6	Aug. 18	18
PiPi-10	10	Aug. 17	Aug. 25	8	Sept. 15	22	4	75	3.4+	10	Sept. 19	33
PiPi-11	11	Sept. 15	Oct. 3	18	Oct. 17	15	28	23	1.5+	3	Nov. 14	60
PiPi-12	12	Oct. 14-16	[4]									

[1] 1914.

[2] Discontinued. Kept out of doors until Jan. 19, 1914, at which time temperature was too low to allow further development. Hence they were brought into a warm greenhouse, maturing as viviparous females Jan. 24.

[3] The actual last-born generation series broken by death of female in cage PiPi-3, so the last-born young of experiment Pi-8 was used to continue the last-born generation series, the cage being numbered PiPi-9.

[4] Matured Nov. 14 and proved to be winged males.

An average of all experiments for the two years, carried through out of doors and apparently under normal natural conditions, was 12.1+ days. As would be anticipated, and as is shown in Tables IV and V, the age at which females began reproducing was shortest during the warmer parts of the year and longest during the early spring and late fall months. In the case where immaturity lasted 56 days the aphis would doubtless have remained immature for a much longer time, possibly all winter, had it been left out of doors under natural conditions. (See footnote 1, Table VI.) From 16 individual experiments, between March 23 and September 21, Mr. R. L. Webster (Folsom, 1909) found that a female begins to reproduce 11 days after birth, on an average.

REPRODUCTIVE PERIOD.

The reproductive period—that is, the time or period during which the insect gave birth to young—varied from 2 to 68 days in 1912 and from 2 to 61 days in 1913, or an average for the two years (53 examples) of 22 days. In computing these averages some records, where the aphis was known to have died from other than natural causes, were not considered. Except in cases where death was due to other than natural causes, the female almost invariably lived several days after the birth of its last young, the length of time varying from 2 or 3 to 28 days.

LONGEVITY.

As is the rule with all of the Aphididæ, the pea aphis lives for a much longer time in the spring and fall, especially in the fall, than in the summer. In our records the total length of life—that is, from date of birth to date of death—of individuals varied from 10 to 85 days in 1912 and from 10 to 78 days in 1913, or an average of 39.1+ days from 51 records made during the two years. Tables IV and V may be referred to for the variation in lengths of life at the different times of the year. In Mr. Webster's experiments reported by Dr. Folsom (1909) the length of life of 16 individuals from as many consecutive generations varied from 13 to 50 days, with an average of 25.4 days.

FECUNDITY OF VIVIPAROUS FEMALES.

The aphis under discussion is one of the most prolific of all plant-lice. We find that a female may give birth to as many as 14 young in a period of 24 consecutive hours. The average number of young per female for all individuals where records were kept in 1912 and 1913 (59 examples) was 3.7+ per day, but this is the average for the entire reproductive period of each female, and as we learned, the birth rate greatly diminishes toward the latter days of its life, often not averaging one young a day. Taking this into consideration we find the average birth rate during the active life of the mother

to be about 7 young per day, or even more. In our experiments individual females bore as many as 124 young, and Dr. J. W. Folsom (1909) reports a case where a single female produced 147 young. In Mr. R. L. Webster's experiment conducted at Urbana, Ill., in 1905 (Folsom, 1909) the average number of young borne by females of 16 consecutive generations was 46, while the average number of young produced by individual females in all our experiments conducted at La Fayette, Ind. (53 examples), excepting a few which were accidentally or prematurely killed, was 68.3+.

From these figures it is not difficult to see why this insect becomes so remarkably abundant, apparently within a few days, on its various hosts, and why it is able, collectively, to ravage and completely destroy crops almost before they become apparent to the casual observer.

SEXUAL FORMS.

Sexual forms may occur in the fall of the year, but there seems to be no uniformity in their production as is the case of certain other plant-lice. For instance, oviparous females may be produced by either wingless or winged females and the same female may produce both viviparous and sexual forms alternately; for example, in one of the experiment cages of 1912 a wingless female gave birth to her first young on October 10 and these proved to be oviparous females; later she gave birth to young which became viviparous females, and still later again bore oviparous females. A number of instances where females gave birth to viviparous and sexual forms alternately were observed in 1912 and 1913. Our earliest record of the birth of individuals of the sexual generation was October 10 in 1912 and October 14 in 1913. Dr. Folsom (1909) found the males in the field as early as October 10 in Illinois, and in one instance, in an experiment cage, an oviparous female was born as early as September 22. At Funkstown, Md., Mr. J. A. Hyslop observed the sexes of this species swarming on an alfalfa field November 12, 1912, the males and oviparous females predominating, although some viviparous females and young were observed. This observation was repeated at the same place by Mr. C. M. Packard October 28, 1913.

From these observations it is impossible to attribute the production of sexes to any particular cause. Certain aphids, notably *Aphis maidi-radicis, Sipha flava, Callipterus trifolii, Chaitophorus negundinis, Eulachnus rileyi,* etc., invariably produce the egg-laying forms toward winter in this latitude, and this may be attributed largely to the weather conditions; but in the case of *pisi,* both viviparous and oviparous forms are commonly borne of the same mother, and in the same line of generations, conducted under exactly identical conditions, reproduction may continue viviparously throughout the winter, while parts of one or more of these generations may become sexual forms. It is noted, however, that sexes are never produced

at any time except in fall or early winter, and climatic conditions no doubt have some direct or indirect influence.

In our experiments oviparous females were produced much oftener than males, probably accountable from the fact that individual males may fertilize several females. The oviparous females are invariably wingless; but we have found both winged and wingless males, the latter in only a few instances in 1911. In the field Mr. Hyslop also observed the wingless male. In the case recorded by him a winged and wingless male were attempting to mate with the same female. To our knowledge these are the only two records of the occurrence of wingless males in America.

Mordwilko (10) has observed wingless males in Russia, and in his writings has described this form.

Copulation takes place soon after the individuals reach maturity, and egg laying commences shortly thereafter. Eggs are laid on the stems and leaves of red clover, according to our observations in Indiana; but Mr. Hyslop, in his observations with this species on alfalfa, mentioned above, found eggs only on the leaves of alfalfa and in no case on the stems, petioles, or axils. We have no records of the sexual forms being produced or eggs being laid on any plants other than red clover and alfalfa. However, Mordwilko (10) has observed the sexual forms on *Medicago falcata*, *Lathyrus latifolius*, and *L. angustifolius*, and Theobald (11) found them on the flat pea (*Lathyrus sylvestris*).

FECUNDITY OF OVIPAROUS FEMALES.

Actual counts of the number of eggs laid by individuals were not made, but dissections of 12 unfertilized females several weeks after maturity showed that they were capable of laying an average of 25 eggs. (See Table VII.) These counts indicate that the fecundity of oviparous females of *pisi* is twice that of the average aphidid.

TABLE VII.—*Number of eggs of Macrosiphum pisi.*

Date.	Number of eggs laid previous to date of dissection.	Number of apparently fully developed eggs found in body.	Number of immature eggs in body.	Total number of eggs exclusive of undeveloped ones.
Dec. 6,1912	1 or 2	27	2+	28 or 29
Do	1 or 2	24	Several	25 or 26
Dec. 10, 1912	Avg. of 2 per ♀	18		20
Do	do	25		27
Do	do	25		27
Do	do	19		21
Do	do	18		20
Do	do	25		27
Do	do	21		23
Do	do	17		19
Jan. 4,1913	2	26		28
Do	2	30		32
Average		23		24.8+

NATURAL CONTROL.

It is doubtful if any species of plant louse is more harassed by enemies than is the pea aphis. According to the observations of other writers, which we are able to corroborate, the common aphis fungus, *Empusa aphidis* (fig. 13), is the most important natural check on the increase of *Macrosiphum pisi*. This fungus thrives under moist conditions, especially when accompanied by warmth, and hence it usually makes its appearance after a few days of rainy weather and more often in summer—that is, during the warmer months. As might be inferred, this fungus is contagious and spreads with wonderful rapidity, frequently, as observed by us, so completely eradicating the insects that it was difficult and sometimes impossible to locate a single living plant louse. Diseased aphids first turn brownish and later become covered with the fungus threads. Thus weather conditions favorable for the growth of Empusa fungus are indirectly important. Furthermore, driving rains destroy great numbers of these plant lice, and very hot, dry weather seems to

FIG. 13.—*Macrosiphum pisi* attacked by a fungus. Enlarged. (Original.)

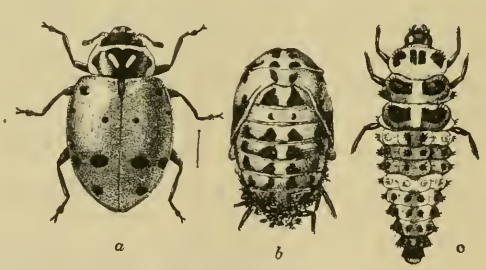

FIG. 14.—The convergent lady-beetle (*Hippodamia convergens*), an enemy of *Macrosiphum pisi*: *a*, Adult; *b*, pupa; *c*, larva. Enlarged. (From Chittenden.)

hinder excessive multiplication, so that weather conditions are a great factor in the natural control of this pest.

Next in importance in the natural control of this aphidid are the ladybirds, and of these no less than nine different kinds are known to prey upon it, namely, *Hippodamia convergens* Guer. (fig. 14), which is probably the most generally common and abundant of all the ladybirds; *H. glacialis* Fab., *H. 13-punctata* L., *H. parenthesis* Say, *Cycloneda munda* Say, *Coccinella 9-notata* Hbst., *Megilla fusci-*

labris Muls., *Adalia bipunctata* L., and *Chilocorus bivulnerus* Muls. Both larvæ and adults feed on the plant lice.

The larvæ of the syrphid flies (Syrphidæ), more generally known under the name of "sweat bees," are important enemies of the pea

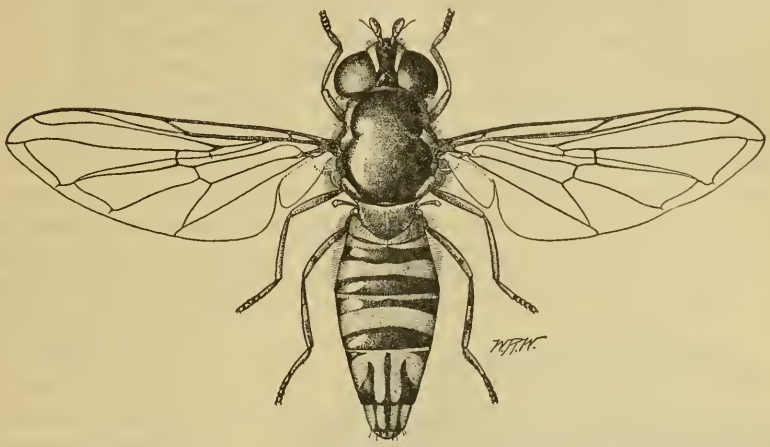

FIG. 15.—*Allograpta obliqua*, a syrphid fly the larva of which preys upon *Macrosiphum pisi*. (Original.)

aphis. The larvæ are sluglike and attack the aphis by piercing it and sucking the body juices. Each larva is capable of devouring many aphides in rapid succession. Johnson reports (1899) that one grower in Maryland, when separating peas, sieved out about 25 bushels of syrphid larvæ, mostly of the species *Allograpta obliqua* Say (figs. 15, 16), which is illustrative of the abundance of these larvæ at times. The adult flies are everywhere abundant in summer, and especially in the neighborhood of heavy aphis infestations. They hover in the air and at brief intervals fly rapidly, but only for short distances. Folsom (1909) enumerates eight species as attacking *Macrosiphum pisi*, namely, *Ocyptamus* (*Baccha*) *fuscipennis* Say, *Platychirus quadratus* Say, *Syrphus americanus* Wied., *S. ribesii* L., *Allograpta obliqua* Say, *Mesogramma marginatum* Say, *M. politum* Say, and *Sphaerophoria cylindrica* Say.

FIG. 16.—*Allograpta obliqua*: Larva. Much enlarged. (From Metcalf.)

Three species of lace-wing fly larvæ (Chrysopidæ), namely, *Chrysopa oculata* Say, *C. rufilabris* Burm., and *C. plorabunda* Fitch, feed on this plant louse. They are predacious in the larval stage, as is the case with the syrphids. The larvæ are provided with a pair of hollow bow-shaped mandibles or jaws, with which they grasp the aphis and through which its juices are sucked. The adults are pale green insects with relatively large lacelike wings, and from this character the common name is derived.

A small pinkish or orange larva (fig. 17) belonging to the family Cecidomyiidæ (*Aphidoletes* sp.)[1] is an active enemy of this plant louse, and although of small size, being only about one-eighth of an inch long, it has a remarkable capacity and is very prolific. It is the more effective because it does not attempt to consume all of the body fluids, as do the syrphids and chrysopids, but seems only to fed upon the juices of the captive plant louse until the latter is dead, soon after which the dead plant louse is discarded and another one attacked. Doubtless the predacious larva mentioned by Fletcher as *Diplosis* sp. was an Aphidoletes.

Other insects which are known to be predaceous on *Macrosiphum pisi* are several true bugs (*Podisus maculiventris* Say, *Euschistus variolarius* P. B., and *Triphleps insidiosus* Say), a tree cricket, *Oecanthus confluens* H. & H., and a beetle, *Podabrus rugulosus* Lec. Another beetle(*P. pruniosus* Lec.), closely related to the last named, has recently been reported by Mr. H. F. Wilson (1913) as feeding on "the vetch aphis (*Macrosiphum pisi* Kalt.?)." A mite (*Rhyncholophus parvus* Banks) is also known to attack this aphidid.

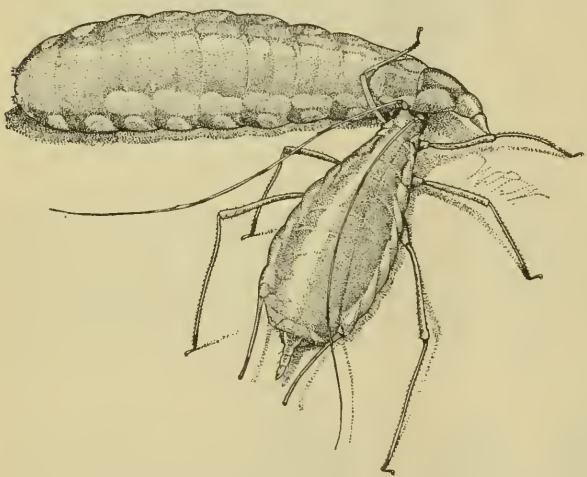

FIG. 17.—Larva of the syrphid fly *Allograpta obliqua*, which preys upon *Macrosiphum pisi*: Enlarged. (Original.)

The pea aphis is attacked by several internal parasites. Aphides thus attacked are inactive and finally die, becoming brown in color, and the adult parasite makes its exit from the dead aphis by cutting a circular hole in the dried skin. The species hitherto reported attacking this aphidid are *Aphidius fletcheri* Ashm. MS., *A. washingtonensis* Ashm., *Trioxys* (*Praon*) *ccrasaphis* Fitch, and *Megorismus fletcheri* Cwfd. In the spring of 1915 Mr. W. B. Hall of this bureau reared *Aphidius rosae* Hal. and *Praon simulans* Prov. of this species collected at Wakeman, Ohio.

METHODS OF ARTIFICIAL CONTROL.

In the clover field the pea aphis is ordinarily held in check by its natural enemies. If it is apparent that this aphis is becoming un-

[1] Since the above was written Dr. E. P. Felt has determined Aphidoletes reared at La Fayette, Ind., in 1915 from larvæ attacking *Aphis gossypii* as *A. meridionalis* Felt. There is little question but that the species attacking *M. pisi* is identical.

duly abundant, the clover should be cut as soon thereafter as possible, since the cutting and drying of the clover will kill most of the insects. Clover which becomes coated with the honeydew of the aphides will not cure properly. Spring pasturing or early cutting back of the clover will check the multiplication of this plant louse.

A more brief general discussion of the pea aphis was published by Dr. F. H. Chittenden as Circular No. 43 of the Bureau of Entomology under the title "The Pea Aphis (*Macrosiphum pisi* Kalt.)," February 25, 1909, pages 1–10. This publication is now out of print, but can be consulted in most agricultural college libraries, as well as public libraries, and in private ones. A farmers' bulletin covering the same subject is in course of preparation.

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[1] Dates in italics refer to the more important references. Dates preceded by an asterisk indicate papers which have been inaccessible to the writer.

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*1899a. JOHNSON, W. G. [*Nectarophora destructor* John.] *In* American Packer, Aug. 1, 1899.

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1899b. JOHNSON, W. G. The destructive pea louse, a new and important economic species of the genus Nectarophora. U. S. Dept. Agr., Div. Ent., Bul. 20, n. s., p. 94–98. Same *in* Sci. Amer., v. 81, no. 21, p. 325, 3 fig., Nov. 18.

Notice of the appearance of this plant-louse, which will be described as new under the name *Nectarophora destructor*, in very destructive numbers throughout the State of Maryland. Notes on remedies, habits of insect, and its natural enemies.

1900. [BUREAU OF ENTOMOLOGY.] The principal injurious insects of the year 1899. U. S. Dept. Agr. Yearbook f. 1899, p. 745–746.

Page 745. Reports serious injury to peas in Atlantic States by *Nectarophora destructor*.

1900a. CHITTENDEN, F. H. Insects and the weather: Observations during the season of 1899. U. S. Dept. Agr., Div. Ent., Bul. 22, n. s., p. 51–64.

Page 58. *Nectarophora destructor* was troublesome in vicinity of Washington past season.

1900b. CHITTENDEN, F. H. The destructive green-pea louse. U. S. Dept. Agr., Div. Ent., Bul. 23, n. s., p. 33–37, fig. 9.

Treats following topics: The important outbreak of 1899; individual records of injury; brief characterization of the insect involved; question of alternate hosts; natural enemies and remedies.

1900. FELT, E. P. 15th Report of the State Entomologist on injurious and other insects of the State of New York, 1899 (Bul. N. Y. State Mus., v. 6, no. 31), p. 533–653.

Pages 538, 567. Reports injury to peas on Long Island by *Nectarophora destructor*

1900a. Fletcher, James. Injurious insects in Ontario during 1899. *In* 30th Ann. Rpt. Ent. Soc. Ontario, p. 106–111.

Page 107. Notice of abundance and injury to field, garden, and sweet peas by *Nectarophora destructor*. Natural enemies and remedies.

1900b. Fletcher, James. Report of the entomologist and botanist. *In* Canada Expt. Farms Rpts. f. 1899, p. 159–204, 23 fig.

Page 170. Reports injury to garden, field, and sweet peas and vetch by *Nectarophora pisi* and quotes from letters (dated from July 29 to October) reporting injury. Notes on natural enemies of the pea louse. Remedies.

1900. Forbes, S. A., and Hart, C. A. The economic entomology of the sugar beet. Univ. Ill. Agr. Expt. Sta., Bul. 60, p. 397–532, 97 fig., 9 pl. Also: *In* 21st Rpt. State Ent. Ill., p. 83.

Page 431. *Nectarophora pisi* reported from Illinois. Said to have been found on beets in Nebraska.

1900. Gibson, Arthur. Notes on insects of the year. Division No. 3, Toronto District. *In* 30th Ann. Rpt. Ent. Soc. Ontario f. 1899, p. 97–98, fig. 60–61.

Page 97. Reports injury to sweet and field peas in 1899 by *Nectarophora destructor*.

1900. Harrington, W. Hague. Notes on insects of the year. Division I, Ottawa District. *In* 30th Ann. Rpt. Ent. Soc. Ontario f. 1899, p. 94–96, fig. 58–59.

Page 95. Injury to sweet peas in 1899 by *Nectarophora destructor*.

1900. Harvey, F. L. Notes on insects and plants. Maine Agr. Expt. Sta., Bul. 61, p. 31–44, March.

Page 31. Reports much damage to garden and field peas in Maine in 1899 by *Nectarophora destructor*.

1900a. Johnson, W. G. The destructive green-pea louse. *In* Canad. Ent., v. 32, no. 2, p. 56–60, fig. 4–6, Feb.

Description of winged and wingless viviparous females as *Nectarophora destructor* n. sp. Distribution of the species and its natural enemies.

*1900b. Johnson, W. G. [*Nectarophora destructor* John.] *In* Canner and Dried Fruit Packer, Feb. 15, p. 42.

Injuries, description, habits, and remedies.

*1900c. Johnson, W. G. [*Nectarophora destructor* John.] Circulars Maryland State Hort. Dept. No. 7 (May 12), No. 11 (May 15), No. 13 (May 31), No. 19 (June 3). Figs.

Describes condition of pest in Maryland and methods being used against it.

*1900d. Johnson, W. G. The green-pea louse in Maryland. *In* Amer. Gard., v. 21, no. 284, p. 375, June 2.

1900e. Johnson, W. G. The destructive pea louse. *In* Rural New Yorker, v. 59, no. 2636, p. 525–526, fig. 178–179, August 4. Also: *In* Strawberry Cult. (The strawberry root louse), v. 7, no. 1, p. 7, August.

1900f. Johnson, W. G. Notes upon the destructive green-pea louse (*Nectarophora destructor* John) for 1900. U. S. Dept. Agr., Div. Ent., Bul. 26, n. s., p. 55–58, 2 pl. Also: *In* 31st Ann. Rpt. Ent. Soc. Ontario f. 1900, p. 99–102

Destructiveness of the pea aphis, with notes on life history and methods of control.

1900g. Johnson, W. G. Notes on insects of economic importance for 1900. U. S. Dept. Agr., Div. Ent., Bul. 26, n. s., p. 80–84.

Page 81. Injuries occasioned by the pea aphis.

1900. Lugger, O. Bugs (Hemiptera) injurious to our cultivated plants. Univ. Minn. Agr. Exp. Sta., Ent. Div., Bul. 69, 259 p., 200 fig., 16 pl. Also: 6th Ann. Rpt. State Ent. Minn.

Page 201. Brief note on injuries in the East and in Wisconsin to peas by *Nectarophora destructor*.

1900a. Phillips, J. L., and H. L. Price. The nature and use of certain insecticides. Va. Agr. Expt. Sta., Bul. 97 (n. s., v. 8, no. 2), p. 11–26, February, 1899.

Page 23. Reports on damage by *Nectarophora destructor* in 1898–1899 and on insecticide tests against this insect.

*1900b. Phillips, J. L., and Price, H. L. The English pea louse. *In* South. Planter, v. 61, no. 4, April.

*1900a. Sanderson, E. D. [*Nectarophora destructor* John.] The destructive pea louse. *In* Amer. Grocer, v. 63, no. 8, p. 13–14, 2 fig., February 21. Also: *In* Amer. Packer, Canner and Dried Fruit Packer, February 15, p. 38, figs.

Description, injuries, habits, enemies, and remedies.

*1900b. Sanderson, E. D. The destructive pea louse. *In* The Canner and Dried Fruit Packer, March, 1900, figs.

1900c. [Sanderson, E. D.] The destructive pea louse. Del. Col. Expt. Sta., Press Bul. 4, 1 p., May 15.

Injury to peas in 1899. Occurrence on clover, mode of spreading to peas, and means of control.

1900d. [Sanderson, E. D.] The green-pea louse. Del. Col. Expt. Sta., Press Bul. 5, 1 p., June 1.

Injury to peas in 1900 in Delaware, susceptibility of different varieties, natural enemies, and control.

*1900e. Sanderson, E. D. The destructive green pea louse. *In* Rural New Yorker, v. 59, no. 2629, p. 413–414, fig. 126–130, June 16.

*1900f. Sanderson, E. D. Pea louse in Wisconsin. *In* Rural New Yorker, v. 59, no. 2644, p. 659, September 29.

1900g. Sanderson, E. D. Notes from Delaware. U. S. Dept. Agr., Div. Ent., Bul. 26, n. s., p. 66–72.

Page 69. Record of the pea louse during 1900. Records numerous enemies of this aphidid and gives remedies.

1900h. Sanderson, E. D. II. The destructive pea louse in Delaware. Del. Col. Agr. Expt. Sta., Bul. 49, p. 14–24, fig. 67, pl. 2–3.

Injury by *Nectarophora pisi*, its past history, brief description, food plants, spread of the pest, natural enemies, and means of control.

*1900. [Slingerland, M. V.] Pea lice in New York State. *In* Rural New Yorker, v. 59, no. 2649, p. 737, November 3.

1900a. Smith, J. B. Report of the Entomologist. *In* 20th Report of the Entomological Department of the New Jersey Agricultural College Experiment Station f. 1899, p. 423–512, 44 fig.

Page 424. First observed injury to peas by *Nectarophora destructor* in 1898. Notices of individual reports of damage by this insect in 1898, and suggests preventive measures.

1900b. Smith, J. B. Insects injurious to fruits. *In* Amer. Agr., v. 66, no. 25, p. 645, December 22.

*1900a. Webster, F. M. [Quoted in Phila. (Pa.) Public Ledger.] April 4, 1904.

Occurrences of the pea louse at Toledo, Ohio.

1900b. Webster, F. M. Insects of the year in Ohio. U. S. Dept. Agr., Div. Ent., Bul. 26, n. s., p. 84–90.

Page 88. Reports occurrence of *Nectarophora destructor* on Canada field peas, as well as red clover and garden peas, in various parts of Ohio. A fungus identified as *Empusa aphidis* destroyed myriads of the aphis.

1900. Weed, C. M. Insect record for 1899. N. H. Col. Agr. Expt. Sta., Bul. 72, p. 61–74, 11 fig.

Page 74. Reports damage to garden and sweet peas in various parts of New Hampshire, due to *Nectarophora destructor*.

1901. [Bureau of Entomology.] The principal injurious insects of the year 1900. U. S. Dept. Agr. Yearbook f. 1900, p. 725–729.

Page 726. Serious injury to peas by *Nectarophora destructor* along Atlantic coast and westward to Wisconsin. Remedies.

1901. Chapais, J. C. L'aphis des pois. *In* Nat. Canad., v. 28, no. 2, p. 17–20, Feb.

Reports serious injury to sweetpeas in August of 1900. Describes the insect (after Johnson). Observations of injury and remedies.

1901a. Chittenden, F. H. Remedies for insect pests in vegetable and flower gardens and conservatories. 4 p., 4 fig. Philadelphia.

Remedies for the pea louse.

1901b. Chittenden, F. H. The destructive green pea louse. U. S. Dept. Agr., Div. Ent., Circ. no. 43. 8 p., 3 fig., May 23.

A concise account of *Nectarophora destructor* Johns. as a pest of peas, under the following headings: Recent injury, descriptive, distribution, extent of injury and method of work, natural enemies, and method of control.

1901. Felt, E. P. Voluntary entomological services of New York State. *In* 16th Report of the State Entomologist on Injurious and Other Insects of the State of New York f. 1900 (Bul. N. Y. State Mus.), v. 7, no. 36, p. 1000–1026.

Pages 1003, 1017. Correspondent reports *Nectarophora pisi* not so injurious on Long Island as previous year. Also reported from Broome County.

1901. Fernald, C. H., and Fernald, H. T. Report of the entomologists. *In* 13th Ann. Rpt. Hatch Expt. Sta. Mass. Agr. Col. f. 1901, p. 84–88, Jan.

Page 87. Injury to peas by pea louse in 1900 but not so great as in 1899.

1901a. Fletcher, James. Injurious insects in Ontario during 1900. *In* 31st Ann. Rpt. Ent. Soc. Ontario f. 1900, p. 62–72, fig. 14–32.

Page 66. *Nectarophora destructor* not as abundant in 1900 as in 1899; notes reported injuries, remedies, and natural enemies.

1901b. Fletcher, James. Report of the entomologist and botanist. *In* Canada Expt. Farms Rpts. f. 1900, p. 195–249+ii, 18 fig.

Page 211. *Nectarophora destructor* was present in same districts as in the preceding year (1899) but in less injurious numbers. Notices of injuries and discussion of natural enemies, especially of the orange larva of a species of Diplosis.

1901c. Fletcher, James. Farm pests; fodder grasses. Evidence of Dr. James Fletcher, Entomologist and Botanist, before the Select Standing Committee on Agriculture and Colonization f. 1901, 25 p.

Page 20. Notice of injuries by the destructive pea aphis.

1901. Harvey, F. L. Notes on insects of the year 1899. *In* 16th Ann. Rpt. Maine Agr. Expt. Sta. f. 1900, p. 31–42.

Page 31. Reports *Nectarophora destructor* abundant and destructive to garden and field peas.

*1901a. Johnson, W. G. The destructive pea-louse. *In* Rural New-Yorker, v. 60, no. 2659, p. 17, fig. 7, Jan. 12.

*1901b. Johnson, W. G. Green pea industry threatened. *In* Amer. Agr., v. 67, no. 6, p. 202–203, 2 fig., Feb. 9.

1901. L., H. H. Pea louse in field peas. *In* Rural New-Yorker, v. 60, no. 2672, p. 267, April 13.

H. H. L. writes of field peas, grown with barley, being ruined in 1900 by the pea aphis. Suggests earlier planting.

1901a. Sanderson, E. D. Some plant lice affecting peas, clover, and lettuce. *In* Canad. Ent., v. 33, no. 2, p. 31–39, pl. 2, Feb.

Description of the winged and wingless viviparous female and winged male, together with comparisons with other species and supposed varieties. Concludes *pisi* of Europe and *destructor* of America identical.

1901b. SANDERSON, E. D. Danger from green pea-louse. *In* Rural New-Yorker, v. 60, no. 2692, p. 268, April 13.

Reply to correspondent who reports injury to fodder peas by the pea louse and of the successful use of whale-oil soap in combating it on garden peas.

1901c. SANDERSON, E. D. The destructive pea louse (*Nectarophora pisi* Kalt.). *In* 12th Ann. Rpt. Del. Col. Agr. Expt. Sta. f. year ending June 30, 1900, p. 169–186, fig. 8, pl. 2–3.

Account contains bibliography, description of the insect, past history, life history, injury, natural enemies, cause of outbreaks, and means of control.

*1901d. SANDERSON, E. D. Successful sprayer for the pea louse. *In* Rural New Yorker, v. 60, no. 2685, p. 481–482, fig. 204–205, July 13.

1901. SMITH, JOHN B. Report of the entomologist. *In* 21st Ann. Rpt. N. J. Agr. Expt. Sta. f. 1900, p. 479–572, 10 fig.

Page 505. General account of the life history of *Nectarophora destructor*. Review of known remedies and preventives.

1902. BRITTON, W. B. First report of the State entomologist. *In* Report of the Conn. Agr. Expt. Sta. f. 1901, pt. 3, p. 227–278+viii, 11 pl., 2 fig.

Pages 238, 276. The pea louse less abundant than in 1899 or 1900. Injuries and remedies.

1902. CHITTENDEN, F. H. The principal injurious insects in 1901. *In* U. S. Dept. Agr. Yearbook f. 1901, p. 674–679.

Page 675. The destructive pea louse not abundant except in a few isolated localities.

1902. FLETCHER, JAMES. Report of the entomologist and botanist. *In* Canada Expt. Farms Rpts. f. 1901, p. 197–262+ii, 19 fig., 1 pl.

Page 212. *Nectarophora destructor*, which occurred in Canada in injurious numbers in 1899 and 1900, almost entirely disappeared in 1901, one report only of injury being received.

*1902. JOHNSON, W. G. Protecting green pea crop from insects. *In* Amer. Agr., v. 69, no. 17, p. 584, April 26.

1902. PETTIT, RUFUS H. Some insects of the year 1901. Mich. State Agr. Col. Expt. Sta., Bul. 200, p. 179–212, 21 fig., May.

Page 198–200. Reference to injury in the United States and its occurrence in Michigan. Remedies.

1902. QUAINTANCE, A. L. Injurious insects of the year. *In* Rpt. Md. Hort. Soc. 4th Ann. Sess. held in Baltimore, Dec. 12 and 13, 1901, v. 4, p. 87–104, fig. 8–22.

Page 101. Less injury past year by pea louse. Injury most noticeable to late peas.

1902a. SANDERSON, E. D. Report of the entomologist. *In* 13th Ann. Rpt. Del. Agr. Expt. Sta. f. 1901, p. 127–199, fig. 13–33.

Page 168. Results of experiments in the control of *Nectarophora pisi* on peas.

1902b. SANDERSON, E. D. Insects injurious to staple crops. 295 p., 162 fig. New York.

Page 182. Brief account of *Nectarophora pisi*.

1902. SMITH, J. B. Report of the entomologist. *In* Ann. Rpt. N. J. Expt. Sta. f. 1901, p. 463–587, 36 fig.

Page 471. The pea louse was not so injurious as in 1900. Describes in detail a new sprayer adapted especially for this pest and efficacy of various remedies.

1902. WEBSTER, F. M., AND NEWELL, W. Insects of the year in Ohio. U. S. Dept. Agr., Div. Ent., Bul. 31, n. s., p. 84–90, Jan.

Page 87. Note on occurrence of the pea louse in Ohio.

1903. CHITTENDEN, F. H. The principal injurious insects in 1902. U. S. Dept. Agr. Yearbook f. 1902, p. 726–733.

Page 727. Reported damage by the pea louse negligible.

1903a. Felt, E. P. Importance of injurious insects introduced from abroad. *In* Report of the State entomologist on injurious and other insects of the State of New York for 1902 (N. Y. State Mus. Bul. 64), p. 116–126.

Page 122. Mentions *Nectarophora pisi* as an introduced species responsible for losses to pea growers in the Atlantic States.

*1903b. Felt, E. P. Importance of injurious insects introduced from abroad. *In* Proc. Soc. Prom. Agr. Sci., 24th Ann. Meet., p. 39–48.

1903. Fletcher, James. Report of the entomologist and botanist. Canada Expt. Farms Rpts. f. 1902, p. 169–201, 5 fig., 1 pl.

Page 179. Brief account of the destructive pea aphis. Worst attack the past season was on grass peas, hairy vetch, and field peas.

1903. Quaintance, A. L. Entomological notes from Maryland. U. S. Dept. Agr., Div. Ent., Bul. 40, p. 47–50, fig. 2.

Page 49. *Nectarophora pisi* was not injurious to peas past season (1902). Growers practice early planting to avoid injury.

1903. Smith, J. B. Report of the entomologist. N. J. Agr. Expt. Sta. Rpt. f. 1902, p. 425–508, 13 fig.

Page 425. Reports absence of pea louse in 1902, except on very late peas.

1904a. Britton, W. E. Third report of the State entomologist. Conn. Agr. Expt. Sta. Rpt. f. 1903, pt. 3, p. 199–286, fig. 27–42, 8 pl.

Page 212. *Nectarophora pisi* less abundant in 1903 than in 1902, though some injury to late peas.

1904b. Britton, W. E. Insect notes from Connecticut. U. S. Dept. Agr., Div. Ent., Bul. 46, p. 105–107.

Page 105. *Nectarophora pisi* less abundant than in 1902, but many late peas were injured.

*1904. Felt, E. P. Pea louse. *In* Country Gent., v. 69, no. 2673, p. 369, April 21.

Methods of controlling *Nectarophora pisi*.

1904. Fletcher, James. Insects injurious to Ontario crops in 1903. *In* 34th Ann. Rpt. Ent. Soc. Ontario f. 1903, p. 62–71, fig. 22–26.

Page 64. Reports injury to field and grass peas by the pea aphis.

1904. Pergande, Theo. On some of the aphides affecting grains and grasses of the United States. U. S. Dept. Agr., Div. Ent., Bul. 44, p. 5–23, 4 fig.

Page 21. The clover plant louse *Macrosiphum trifolii* is here described as new. Reports what he considers same species from wheat (*Triticum vulgare*), oats (*Avena sativa*), red clover (*Trifolium pratensis*), strawberry, sow-thistle (*Sonchus oleraceus*), and dandelion (*Taraxacum dens-leonis*).

1904–1906. Sanborn, C. E. Kansas Aphididae with catalogue of North American Aphididae and with host-plant and plant-host list. Pt. I–II. *In* Kans. Univ. Sci. Bul., v. 3, no. 1, p. 1–82, 22 pl., July, 1904, and v. 3, no. 8, p. 225–274, April, 1906.

Describes winged viviparous female of *Macrosiphum pisi* and reports taking it on rose. In the host plant catalogue the following hosts of *Macrosiphum pisi* are given: *Capsella bursa-pastoris*, cultivated beet, *Lathyrus odoratus*, cultivated pea, *Pisum sativum*, *Spiraea ulmariae*, *Trifolium repens*, *Urtica gracilis*, and *Urtica dioica*.

1904. Sanderson, E. D. Insects of 1903 in Texas. U. S. Dept. Agr., Div. Ent., Bul. 46, p. 92–96.

Page 96. Reports injury to garden peas in Texas by *Nectarophora pisi*.

1904. Smith, J. B. Report of the entomologist. *In* Rpt. Ent. Dept. N. J. Agr. Col. Expt. Sta. f. 1903, p. 557–659, 32 figs.

Page 563. Late peas were badly infested with the pea-louse.

1904. Stene, A. E. When to spray. Formulas and notes on spraying. R. I. Agr. Expt. Sta., Bul. 100, p. 121–148, 6 figs.

Page 129. Means against green pea louse.

1905. Chittenden, F. H. The principal injurious insects of 1904. U. S. Dept. Agr. Yearbook f. 1904, p. 600–605.

Page 604. Only few complaints of injury by *Nectarophora destructor* reported from Colorado.

1905. Felt, E. P. 20th Report of the State Entomologist on injurious and other insects of the State of New York f. 1904. *In* N. Y. State Mus., Bul. 97, p. 359–597, 24 fig., 19 pl.

Pages 408, 416. Brief notes on life history, natural enemies, and remedies for *Nectarophora pisi*.

1905. Fletcher, James. Insects injurious to grain and fodder crops, root crops, and vegetables. Canada Cent. Expt. Farm, Bul. 52, 48 p., 8 pl. June.

Page 27. Brief account of injuries by *Nectarophora pisi*, and remedies.

1905. Pettit, Rufus H. Insects of the garden. Mich. State Agr. Col. Expt. Sta., Dept. Ent., Bul. 233, 77 p., 65 fig.

Page 40. Host plants and remedies for *Nectarophora pisi*.

1906. [Bureau of Entomology.] The principal injurious insects of 1905. *In* U. S. Dept. Agr. Yearbook f. 1905, p. 628–636.

Page 629. A few reports of injury by *Nectarophora destructor*.

1906. Conradi, Albert F. Insects of the garden. Tex. Agr. Expt. Sta., Bul. 89, 52 p., 44 fig.

Page 4. *Nectarophora destructor* apparently widely distributed in Texas. Natural enemies and remedies.

1906. Fletcher, James. Report of the entomologist and botanist. *In* Canada Expt. Farms Rpts. f. 1905, p. 59–81.

Page 67. Refers to extensive destruction of pea crops in Canada in 1899.

1907. Bethune, C. J. S. Injurious insects of 1906 in Ontario. *In* 37th Ann. Rpt Ent. Soc. Ontario f. 1906, p. 45–56, fig. 3–17.

Page 49. Reports occurrence of plant lice on sweet peas.

1907. Hitchings, E. F. Second Ann. Rpt. of the State Entomologist of Maine f. 1906, 77 p., 19 fig., 1 pl.

Page 4. *Nectarophora pisi* reported from several localities in Maine.

1908. [Bureau of Entomology.] Principal injurious insects of the year 1907 U. S. Dept. Agr. Yearbook f. 1907, p. 541–552.

Page 544. *Macrosiphum pisi* reported rather more abundant than usual. Louisiana reported as a new habitat.

1908. Cæsar, L. The annual meeting of the entomological society of Ontario. *In* Jour. Econ. Ent., v. 1, no. 6, p. 397–401, December.

Page 399. Serious damage to the late peas by the pea aphis was reported. Aphis fungus effective in some localities.

1908. Gossard, H. A. Spring practice in economic zoology. Ohio Agr. Expt. Sta., Bul. 198, p. 15–88+viii, 9 pl., November.

Page 86. Brief description of *Nectarophora destructor*, its injury to peas, and remedies.

1908. Newell, Wilmon, and Rosenfeld, Arthur H. A brief summary of the more important injurious insects of Louisiana. *In* Jour. Econ. Ent., v. 1, no. 2, p. 150–155, April.

Page 153. Reports injury to cowpeas by *Nectarophora pisi*.

1909. Barre, H. W., and Conradi, A. F. Treatment of plant diseases and injurious insects in South Carolina. S. C. Agr. Expt. Sta., Bul. 141, 52 p., 1 fig.

Page 41. Means against green pea louse.

1909. [Bureau of Entomology.] The principal injurious insects of the year 1908. *In* U. S. Dept. Agr. Yearbook f. 1908, p. 567–580.

Page 571. *Macrosiphum pisi* was more injurious than for many seasons.

1909a. Chittenden, F. H. The pea aphis. U. S. Dept. Agr., Bur. Ent., Circ. 43, ed. 2, 10 p., 7 fig., Feb. 25.

Revised account of an earlier edition. See 1901, Chittenden.

1909b. Chittenden, F. H. Insects Injurious to Vegetables. 262 p., 163 fig., New York.

Page 114. Concise account of *Nectarophora pisi* as a pest to garden peas.

1909. Crawford, J. C. Notes on some Chalcidoidea. *In* Canad. Ent., v. 41, no. 3, p. 98–99, March.

Describes "*Megorismus Fletcheri*" n. sp., which was reared from *Nectarophora pisi* at Ottawa, Canada.

1909. Davidson, W. M. Notes on Aphididae collected in the vicinity of Stanford University. *In* Jour. Econ. Ent., v. 2, no. 4, p. 299–305, August.

Page 304. Reports *Macrosiphum pisi* from *Urtica holosericea* and Lathyrus. (The specimens from *Urtica* have been examined by the writer and prove not to be *pisi*. J. J. D.)

1909. Folsom, J. W. The insect pests of clover and alfalfa. Univ. Ill. Agr. Expt. Sta., Bul. 134, p. 113–197, 35 fig., 2 pl., April. Also *in* 25th Rpt. State Ent. Ill., p. 41–124, 35 fig., 2 pl.

Page 138. Important contribution, including distribution of the insect, its food plants, injury, descriptions, life history, habits, natural enemies, control, and bibliography of important literature.

1909. Gibson, Arthur. Insects of the year 1908 at Ottawa. *In* 39th Ann. Rpt. Ent. Soc. Ontario f. 1908, p. 116–120, fig. 31–32.

Page 119. *Nectarophora pisi* reported abundant on field and sweet peas. Notes parasite reared.

1909. Hunter, S. J. The green bug and its natural enemies. Univ. Kans. Bul., v. 9, no. 2, 221 p., 66 fig., 3 pl., folded tables 31–33.

Page 154. Unsuccessful experiments attempting to parasitize *Macrosiphum trifolii* with *Lysiphlebus tritici*. (Identification of the aphid doubtful. J. J. D.)

1909. Jarvis, C. D. Control of insects and of plant diseases. Storrs Conn. Agr. Expt. Sta., Bul. 56, p. 220–282, pl. 5–11, April.

Page 258. Remedies against pea louse.

1909. Newell, Wilmon, and Rosenfeld, Arthur H. Some common insects injurious to truck crops. State Crop Pest Comm. of La., Cir. 27, p. 93–131, 21 fig., July.

Page 108. Brief account of *Macrosiphum pisi*, including remedies and enemies.

1909. Swenk, Myron H. The principal insects injurious to horticulture during 1908–1909. *In* 40th Ann. Rpt. Nebr. Hort. Soc. f. 1908 and 1909, p. 75–128, 16 pl.

Page 104. *Nectarophora destructor* reported injuring sweet peas.

1910. Bethune, C. J. S. Observations on Ontario insects in 1909. *In* 40th Ann. Rpt. Ent. Soc. Ontario f. 1909, p. 63–67.

Page 63. Garden peas attacked by plant lice.

1910. Davidson, W. M. Further notes on the Aphididae collected in the vicinity of Stanford University. *In* Jour. Econ. Ent., v. 3, no. 4, p. 372–381, fig. 28–29, Aug.

Page 380. Records *pisi* from *Vicia* sp., cultivated bean, and *Urtica holosericea*. (See notes under 1909, Davidson.)

1910. Essig, E. O. Aphididae of Southern California. V. *In* Pomona Col. Jour. Ent., v. 2, no. 4, p. 335–338, fig. 124–125, Dec.

Page 336. Describes winged and wingless viviparous female *Nectarophora pisi*.

1910. Fullaway, David T. Report of the entomologist. *In* Ann. Rpt. Hawaii Agr. Expt. Station f. 1909, p. 17–46, 8 fig.

Page 23. Describes *Macrosiphum trifolii* Perg. from specimens collected on *Sonchus oleraceus*. (The writer has examined these specimens and they prove not to be *Macrosiphum trifolii* Perg. J. J. D.)

1910. Gibson, Arthur. Reports on insects of the year. *In* 40th Ann. Rpt. Ent. Soc. Ontario f. 1909, p. 9–14.

Page 14. Occurrences of *Nectarophora pisi* on sweet peas but less numerous than in 1908. Parasite mentioned.

1910. Pettit, R. H. Insects of field crops. Mich, State Agr. Col. Expt. Sta., Bul. 258, p. 36–84, 51 fig., February.

Page 47. Briefly noted as a pest on peas.

1910. Rosenfeld, Arthur H. Insects notably injurious in Louisiana during 1908 and 1909. *In* Jour. Econ. Ent., v. 3, no. 2, p. 212–217, April.

Page 214. Considerable injury by *Nectarophora pisi* but less than in 1907.

1910. Smith, J. B. Annual Report of the New Jersey State Museum Including a Report of the Insects of New Jersey, 1909. Trenton.

Page 118. [Nectarophora] Throughout the State south of Piedmont Plain and seasonably abundant and destructive.

1910. Saunders, William. Report of the Division of Entomology and Botany. *In* Canada Expt. Farms Rpts. f. 1909, p. 37–64.

Page 56. Reports serious injury to garden, field, and sweet peas by *Nectarophora pisi* in Quebec and Ontario. Number of enemies noted, including a species of Aphidoletes and a new chalcid parasite (*Megorismus fletcheri* Crawf.) Remedies.

1910. Williams, T. A. The Aphididae of Nebraska. *In* Univ. (Nebr.) Studies, v. 10, no. 2, p. 85–175, April.

Page 168. Reported for clover in Nebraska.

1911. Cæsar, Lawson. Insects of the year in Ontario f. 1910. *In* 41st Ann. Rpt. Ent. Soc. Ontario f. 1910, p. 21–27.

Page 26. *Nectarophora destructor* reported destroying field of peas. Also report of cattle poisoning from eating infested vines.

1911a. Davis, J. J. List of Aphididae of Illinois, with notes on some of the species. *In* Jour. Econ. Ent., v. 4, no. 3, p. 325–331, fig. 10, pl. 10, June.

Page 330. Lists *pisi* from Illinois under names *trifolii* and *ulmariae*. White sweet clover is a new food plant listed.

1911b. Davis, J. J. Preliminary report on the more important insects of the truck gardens of Illinois. *In* Ill. Farmers' Institute Circ. 4, 1911, 50 p., 42 fig. Also *in* 26th Ann. Rpt. State Ent. Ill., p. 99–160, 42 fig. Also *in* Ill. Farmers' Institute Report, v. 16, p. 216–263, fig. 1–42.

Page 34. Brief account of *Macrosiphum pisi* as pest on garden peas, and remedies.

1911c. Davis, J. J. Williams' "The Aphididae of Nebraska;" a critical review. *In* Univ. (Nebr.) Studies, v. 11, no. 3, 39 p. (p. 193–291), 8 pl., July.

Page 34. Listed.

1911a. Essig, E. O. Host index to California plant lice (Aphididae). *In* Pomona Col. Jour. Ent., v. 3, no. 2, p. 457–479, May.

Compiled list of hosts for *Macrosiphum ulmariae* includes sweet pea (*Lathyrus odoratus*), wild pea (*Lathyrus* sp.), pea (*Pisum sativum*), nettle (*Urtica holosericea*), vetch (*Vicia sativa*).

1911b. Essig, E. O. Annual Report of the work of the County Horticultural Commissioner for the year ending June 30, 1911. Ventura Co. Hort. Com., Bul. 2, 60 p., 49 fig.

Page 48. Figures *Macrosiphum destructor* and mentions it as a pest of peas and vetches.

1911. Gossard, H. A. Fall manual of practice in economic zoology. Ohio Agr. Expt. Sta., Bul. 233, p. 53–164+vii, 2 fig., 11 pl., Nov.

Page 78. Advocates late cutting or pasturing of clover, especially first-year clover, as a remedy against *Macrosiphum pisi*.

1911. Gibson, Arthur. Reports on insects of the year. Division No. 1, Ottawa District. *In* 41st Ann. Rpt. Ent. Soc. Ontario f. 1910, p. 11–16.

Page 16. Occurrence on field and sweet peas but not especially injurious. Several natural enemies noted.

1911. Gillette, C. P. Plant louse notes, family Aphididae. *In* Jour. Econ. Ent., v. 4, no. 4, p. 381–385, pl. 16, Aug.

Page 383. Reports *Macrosiphum pisi* from Albany, N. Y., on red clover, and from Colorado on garden and sweet pea, alfalfa, and sweet clover (*Melilotus alba*).

1911. Gossard, H. A. Entomological review of the year 1910. *In* Jour. Econ. Ent., v. 4, no. 2, p. 203–209, April.

Page 208. Reports *Macrosiphum pisi* abundant in northwestern Ohio, some fields of clover dying out after the clover was cut. Droughty conditions probably responsible for unusual abundance of the aphid.

1911a. Hewitt, C. Gordon. Report of the entomologist. *In* Canada Expt. Farms Repts. f. 1910, p. 223–250, 3 pl.

Page 243. *Nectarophora pisi* was destructive in Quebec and Ontario from July to September.

1911b. Hewitt, C. Gordon. Report of the Dominion Entomologist. *In* Canada Expt. Farms Rpts. f. 1911, p. 202–235, 3 fig., pl. 5–7.

Page 230. *Macrosiphum destructor* was present in most parts of Ontario and appeared to check growth of plants.

1911. Patch, Edith M. *Macrosiphum destructor* and *Macrosiphum solanifolii*. Maine Agr. Expt. Sta., Bul. 190, p. 81–92, fig. 59–72, June.

Discussion of characters of these two species, their differences, and insectary host-plant tests.

1911. Ruggles, A. G., and Stakman, E. C. Orchard and garden spraying. Univ. Minn. Agr. Expt. Sta., Bul. 121, 32 p., March.

Page 30. Remedies for sweet-pea plant louse.

1911. Williams, T. A. The Aphididæ of Nebraska. *In* University [Nebraska] Studies, v. 10, no. 2, f. 1910, p. 85–175, April.

Page 84. Reported for clover in Nebraska.

1912a. Essig, E. O. Plant lice. *In* Proc. of 40th Fruit Growers Conv. of the State of Cal. f. 1911, p. 11–24, 3 fig.

Page 15. *Macrosiphum destructor* included as one of the injurious aphidids of California.

1912b. Essig, E. O. Plant lice affecting citrus trees. Pt. I. Mo. Bul. Cal. State Com. Hort., v. 1, no. 4, p. 115–133, fig. 40–45, March.

Page 126–127. Compares *Macrosiphum destructor* with *Macrosiphum rosae* and *Macrosiphum citrifolii*.

1912. Morrison, Harold. A preliminary list of the plant-lice or Aphididæ of Indiana. *In* Fifth Annual Report of Indiana State Entomologist f. 1911–1912, p. 195–236, 33 (unnumbered) fig., 3 pl.

Page 232. Occurrence of *Macrosiphum pisi* in Indiana, injuries and remedies.

1912. O'Kane, W. C. Injurious Insects. 414 p., 606 fig. New York.

Page 200. Brief account of *Macrosiphum pisi* as a pest on peas.

1912. Sanborn, C. E. Garden and truck crop insect pests. Okla. Agr. and Mech. Col. Agr. Expt. Sta., Bul. 100, 76 p., 70 fig.

Page 43. Brief account of *Macrosiphum pisi*, including remedies.

1912. Sanderson, E. D. Insect Pests of Farm, Garden, and Orchard. xii+684 p., 513 fig.

Page 322. General account of the pea aphis (*Macrosiphum pisi*), its natural enemies and control.

1913. Davis, J. J. The Cyrus Thomas collection of Aphididae, and a tabulation of species mentioned and described in his publications. Ill. State Lab. Nat. Hist. Bul., v. 10, art. 2, p. 97–121, pl. 6–7.

Page 98. Examination of type slide of species described by Thomas as *Siphonophora pisi*.

1913. Essig, E. O. Injurious and beneficial insects of California. Mo. Bul. Cal. State Com. Hort., v. 2, nos. 1 and 2, p. xxxi+367, 321 fig., Jan. and Feb.

Pages 73, 203. Brief notes on *Macrosiphum destructor* and remedies.

1913. Hewitt, C. Gordon. Report of the Dominion Entomologist. *In* Canada Expt. Farms Rpts. f. 1912, p. 173–187, 1 pl.

Page 184. The destructive pea aphis reported injuring garden crops.

1913. Lovett, A. L. Insect pests of truck and garden crops, 1913. Oregon Agr. Col. Bul. 91 (Ext. Ser., no. 4), 39 p., 12 fig.

Page 16. Brief account of *Macrosiphum pisi* and means of control.

1913. Morrill, A. W. Notes on important insects of the year. *In* Fifth Annual Report of the Arizona Commission of Agriculture and Horticulture, June 30, 1913, p. 33–48, fig. 7–11.

Page 37. Reports injuries to garden peas by *Macrosiphum pisi*. Remedies.

1913. Wilson, H. F. Notes on *Podabrus pruinosus*. *In* Jour. Econ. Ent., v. 6, p. 457–459, 1 fig., December.

Notes on the beetle, *Podabrus pruinosus*, which has proved efficient in destroying aphidids among other species *Macrosiphum pisi*. Briefly describes various stages of the beetle.

1914. Britton, W. E., and Walden, B. H. Field tests in controlling certain insects attacking vegetable crops. *In* 13th Rpt. State Ent. (Ann. Rpt. Conn. Agr. Expt. Sta., pt. 3) f. 1913, p. 232–237.

Page 235–237. Reports *Macrosiphum pisi* destructive to peas past season and experiments in methods of control.

1914. Cæsar, L. Insects of the season in Ontario. *In* 44th Ann. Rpt. Ent. Soc. Ont. f. 1913, p. 49–53.

Page 52. *Macrosiphum pisi* was troublesome in a few localities in southwestern Ontario in 1913.

1914. Smith, L. B. Control of green pea aphis in 1914. (*Macrosiphum pisi.*)—A preliminary report. Virginia Truck Sta. Bul. 13, p. 301–312, fig. 66.

Remedies, based on recent spraying experiments, for the control of *Macrosiphum pisi* as a pest to peas are given.

1915. Branigan, E. J. [Insect Notes.] *In* Mo. Bul. California State Com. Hort., v. 4, no. 5–6, p. 285, May–June.

Macrosiphum destructor reported damaging pea crops in Alameda County.

1915. Cæsar, L. Insects of the season in Ontario. *In* 45th Ann. Rpt. Ent. Soc. Ontario f. 1914, p. 42–46.

Page 45. Reports injury to late peas by *Macrosiphum pisi.*

1915. Essig, E. O. Injurious and beneficial insects of California. Supplement Mo. Bul. California State Com. Hort., v. 4, no. 4, lxxxi+541 p., 503 fig.

Page 104. Brief account of *Macrosiphum pisi.*

1915. Lochhead, W. Brief notes on some of the injurious insects of Quebec, 1914. *In* 45th Ann. Rpt. Ent. Soc. Ontario f. 1914, p. 59–61.

Page 60. Reports considerable injury to peas by *Macrosiphum pisi.*

1915. Petch, C. E. Insects injurious in southern Quebec, 1914. *In* 45th Ann. Rpt. Ent. Soc. Ontario f. 1914, p. 70–71.

Page 71. Reports considerable injury by *Macrosiphum pisi.*

1915. Ross, W. A. Reports on insects of the year. Division No. 7, Niagara District. *In* 45th Ann. Rpt. Ent. Soc. Ontario f. 1914, p. 22–25.

Page 24. *Macrosiphum pisi* was very destructive to peas.

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IIV. INSECTS.

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 278

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER October 5, 1915

MISCELLANEOUS INSECTICIDE INVESTIGATIONS

By

E. W. SCOTT and E. H. SIEGLER, Entomological Assistants,
Deciduous-Fruit Insect Investigations

CONTENTS

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INTRODUCTION.

Numerous experiments with miscellaneous insecticides and spray combinations, including tests of a new and promising arsenical, namely, arsenate of calcium, were conducted in connection with other work at the field station for deciduous-fruit insect investigations, at Benton Harbor, Mich., during the seasons of 1912, 1913, and 1914. Various homemade and proprietary insecticides, alone and in combination with other sprays, were tested in the laboratory and in the field. This work was done under the instructions of Dr. A. L. Quaintance, in charge of Deciduous-Fruit Insect Investigations, and much valuable assistance in carrying out the work was rendered by Messrs. J. H. Paine, H. G. Ingerson, and D. M. Hamilton.

EXPERIMENTS, 1912.

A series of poison-feeding experiments were made to determine the comparative killing effect of various arsenicals and also doubtful stomach poisons on different species of chewing insects. At the beginning of the tests 32 different materials were used, but since the

[1] See key to the table of insecticides on page 43.

Note.—This bulletin describes experiments with various chemicals, singly and combined, for the destruction of insect pests. It will be of interest to horticulturists in general and apple growers in particular.

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first few experiments showed that many of these were of little value as stomach poisons, their use was discontinued.

A few homemade preparations were tested in the course of these experiments. Those used in 1912 were arsenate of iron, arsenate of zinc, and arsenite of lime. The methods of preparation of these materials were as follows:

Arsenate of iron was prepared by dissolving 4 pounds of sodium-arsenate crystals and 4 pounds of iron sulphate each in 2 gallons of hot water. The iron-sulphate solution was then poured slowly into the sodium-arsenate solution, the solution being stirred vigorously at the same time. Arsenate of iron was used at a rate equal to 0.8 pound of sodium arsenate to 50 gallons of water for the ordinary strength.

The arsenate of zinc (homemade) was prepared in the same way as arsenate of iron, sodium arsenate and zinc sulphate being used, and the strength being based upon the sodium-arsenate content, the same as for arsenate of iron.

Arsenite of lime was prepared by boiling 2 pounds of white arsenic and 2 pounds of sal soda in 1½ gallons of water until thoroughly dissolved, and this was used to slake 4 pounds of stone lime. After slaking, enough water was added to bring the total to 2 gallons. This was used at the rate of 2 pints to 50 gallons of water, which is equivalent to one-fourth pound of white arsenic to 50 gallons of water.

LABORATORY TESTS.

During the season of 1912 the fall webworm (*Hyphantria cunea* Drury) was used for all the experiments, since this insect could be readily obtained in large numbers, and proved to be an ideal species for handling in the laboratory. Very young larvæ, usually 3 or 4 days old, were used in all the tests. The larvæ were fed with foliage of the wild black cherry (*Prunus serotina*), which was found to be a favorite food plant of the fall webworm in Michigan. Twigs having from 20 to 30 leaves each were sprayed by means of a large atomizer of the type in which quart jars are used as a container for the liquid, and the stems of the twigs were placed in small glass jars containing water.

After the spray had thoroughly dried, allowing from 6 to 12 hours, 20 insects were placed on the leaves of each twig. A large paper bag was then placed over the twig and held to the glass by means of a rubber band to prevent the escape of the larvæ. At each examination the bag was removed and the dead larvæ taken out and counted. When all the insects were dead or had pupated, as the case might be, the amount of foliage consumed was measured in square inches. A sheet of celluloid, cross-sectioned to 0.01 of a square inch, was utilized for this purpose. These measurements were easily taken where effective poisons were used, as the young larvæ died before very

much foliage had been consumed. In other cases, where the entire leaf except the midrib and larger veins was consumed, the measurement was obtained by measuring an average-sized leaf and substituting it for the leaf which had been destroyed. Careful attention was given to the condition of the foliage throughout the experiments so as to supply the larvæ with palatable food at all times.

Experiment I.

Comparison of the killing effect of doubtful stomach poisons with various arsenicals on larvæ of the fall webworm.

In this experiment the arsenite of zinc compounds and other proprietary insecticides were used at the strengths recommended by the manufacturers. The homemade arsenical compounds, where sodium arsenate was employed, were used at a rate to equal 0.8 pound sodium-arsenate content to 50 gallons of water, except in the case of arsenate of iron, which was used double strength. Arsenite of lime, homemade, was used at the rate of 2 pints to 50 gallons of water. All other compounds containing arsenic were used at a strength equivalent to 2 pounds of arsenate of lead paste to 50 gallons of water. These calculations were based upon a 15 per cent arsenic-oxid (As_2O_5) content in arsenate of lead paste. Compounds containing no arsenic were used at the rate of 6 pounds to 50 gallons of water. The larvæ used in this test were about 4 days old. The results are given in Table I.

TABLE I—*Tests of the killing effect of various arsenicals and doubtful stomach poisons on the fall webworm.*

[Experiment started July 13, 1912, Benton Harbor, Mich.; 20 larvæ in each lot.]

Name and dilution.	Dates of examination and number of larvæ dying on each date.																						Number of larvæ pupated.	Total number dead.	Number days required to kill.	Square inches foliage consumed.
	July.														August.					September.		October.					
	15	16	17	18	19	20	21	22	23	24	25	26	27	29	2	4	8	14	25	2	13	3	18				
Arsenate of lead,[1] di., 1–55	3	2	7	1	4	3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	20	7	0.23
Arsenate of lead, tri., 1–42	2	4	1	3	4	2	2	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	20	9	.28
Arsenate of lead, di. and tri., 1–50	1	1	3	1	2	6	6	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	20	8	1.40
Arsenate of lead, triplumbic, com. (1), 2–50	1	1	1	2	3	1	0	2	2	3	1	1	....	....	....	....	....	....	....	....	....	....	....	.....	[2]18	13	.70
Arsenate of lead, com. (2), 2–50	5	7	5	1	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	20	7	.37
Arsenate of lead, com. (3), 2–50	3	6	6	3	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	20	7	.39
Arsenate of calcium, c. p. (powder), 1–52	4	2	3	4	1	2	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	[2]18	9	.02
Arsenate of iron, c. p. (powder), 2–50	4	7	2	0	1	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	[2]16	8	.17
Arsenate of iron, h. m., $1\frac{8}{10}$–50	9	3	3	0	2	0	1	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	20	9	.40
Arsenate of zinc, c. p. (powder), 1–46	1	4	4	3	0	2	2	3	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	20	10	.46
Arsenate of zinc, h. m., $\frac{8}{10}$–50	0	6	9	4	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	20	6	.12
Arsenic sulphid, 1–54	0	0	2	0	0	3	0	0	0	0	0	1	1	9	3	....	....	....	....	....	....	....	....	.....	[2]19	19	2.80
Arsenic tersulphid, $\frac{1}{2}$–50	1	5	8	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	[2]18	5	.16
Arsenic trioxid, $\frac{1}{2}$–56	1	3	7	2	3	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	20	7	.25
Arsenite of lime, 2 pts.–50	2	4	3	1	1	3	4	1	0	1	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	20	11	.33
Arsenite of zinc[1] (1), $\frac{1}{2}$–43	6	12	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	20	5	.12
Arsenite of zinc (2), 1–50	6	0	3	2	2	2	0	2	1	1	1	....	....	....	....	....	....	....	....	....	....	....	....	.....	20	12	.60
Arsenite of zinc (3), $\frac{3}{4}$–50	2	3	0	1	1	0	0	3	6	2	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	[2]18	11	.93
Arsenite of zinc (4), $\frac{3}{4}$–50	8	8	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	20	4	.07
Barium chlorid, 6–50	1	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	4	4	[2]10	97	67.75
Barium sulphate, 6–50	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	3	0	0	0	3	....	4	[2]8	82	99.86
Calcium chlorid, 6–50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	3	0	1	7	[2]7	97	62.00
Copper oxid, 6–50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	2	1	0	2	8	[2]9	97	176.00
Lead acetate, 6–50	0	0	0	0	0	0	0	0	0	0	0	2	1	1	1	0	0	0	2	0	1	0	2	4	[2]9	97	122.00
Lead carbonate, 6–50	0	1	0	0	1	2	2	0	0	0	0	0	0	0	2	0	0	1	1	1	0	0	....	6	[2]11	82	80.00
Lead chromate, 4–50	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	3	1	7	3	....	....	....	....	.....	[2]16	43	3.72
Lead oxid, 6–50	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	....	....	5	[2]6	62	81.96
Lead peroxid, 6–50	0	2	0	0	0	0	0	1	0	1	1	1	1	1	0	0	0	0	0	1	1	1	....	.....	[2]10	82	18.90
Mercury bichlorid, $\frac{3}{4}$–50	0	2	1	2	2	1	3	6	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.....	[2]17	9	.27
Zinc chlorid, 3–50	1	0	0	0	1	1	0	0	0	0	0	0	1	2	1	4	3	....	....	....	....	....	....	.....	[2]14	26	3.73
Zinc oxid, 6–50	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	2	8	1	2	....	....	.....	[2]16	62	9.48
Zinc sulphate, 6–50	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	1	4	5	0	0	1	.....	[2]14	97	12.37
Check (unsprayed) 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0	....	9	[2]4	82	155.55
Check (unsprayed) 2	2	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	....	12	[2]7	82	131.38
Check (unsprayed) 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	....	9	[2]3	82	192.00

[1] Arsenate of lead, di.=diplumbic powder; tri.=triplumbic powder; di. and tri.=mixture of diplumbic and triplumbic powder; com. (1), (2), (3)=commercial paste. Arsenite of zinc, (1)=chemically pure; (2)=paste, commercial; (3)=powder, commercial; (4)=powder, commercial; c. p.=chemically pure; h. m.=homemade.

[2] Remainder escaped.

As will be noted, while the triplumbic arsenate of lead was very effective against the larvæ, it was somewhat slower in its killing effect than the diplumbic and the mixture of diplumbic and triplumbic arsenate of lead. This held true in the other experiments that follow. Of the three commercial arsenates of lead, commercial (1), which consisted of the triplumbic form, required a greater length of time to kill the larvæ than was required by the other two commercial brands, which consisted mainly of the diplumbic form.

Arsenate of iron, both chemically pure and homemade, was used at double strength, owing to indications of slow killing effect in previous tests. At this strength it was somewhat slower than many of the other arsenicals. Like results will be noted in later experiments with this material.

The arsenates of zinc were effective and seemed to be safe to use on the foliage.

Arsenic sulphid, arsenic tersulphid, arsenic trioxid, arsenite of lime, and the arsenites of zinc were effective, but burned the foliage more or less seriously.

Mercury bichlorid and zinc chlorid, while effective, were very injurious to the foliage.

All the other compounds were ineffective.

Experiment II.

COMPARISON OF THE KILLING EFFECT OF VARIOUS ARSENICALS AND DOUBTFUL STOMACH POISONS COMBINED WITH LIME-SULPHUR SOLUTION ON LARVÆ OF THE FALL WEB-WORM.

In Table II are given the results of using lime-sulphur at the rate of 1½ gallons to 50 gallons of spray in combination with all the materials used. Little difference was noted from the use of these combinations of lime-sulphur with the arsenicals. However, in case of the materials which had no effect on the larvæ when used alone a marked difference was evident from the addition of lime-sulphur. In all cases the larvæ were killed, the length of time of killing varying considerably with the material used. The difference no doubt was largely due to the difference in chemical reaction between the material and the lime-sulphur. Lime-sulphur alone killed the 20 larvæ in 15 days with only 0.73 square inches of foliage consumed. In Table II are shown the results.

TABLE II.—*Tests of the killing effect of various arsenicals and doubtful stomach poisons combined with lime-sulphur on the fall webworm.*

[Experiment started July 20, 1912, Benton Harbor, Mich.; 20 larvæ in each lot.]

Name and dilution.	Dates of examination and number of larvæ dying in each lot.																									Total number dead.	Number days required to kill.	Square inches foliage consumed.
	July.									August.														September.				
	22	23	24	25	26	27	28	29	31	2	4	6	8	10	12	14	16	19	21	24	26	28	2	19	30			
Lime-sulphur, 1½–50, combined with the following:																												
Arsenate of lead,[1] di., 1–55	0	1	1	0	2	4	1	4	5	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	13	0.16
Arsenate of lead,[1] tri., 1–42	0	0	0	1	0	3	0	3	6	1	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	[2] 16	15	2.25
Arsenate of lead,[1] di. and tri., 1–50	2	1	1	4	4	7	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	8	.15
Arsenate of lead,[1] triplumbic, com. (1), 2–50	1	2	0	1	0	5	0	5	4	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	[2] 19	13	.44
Arsenate of lead,[1] com. (2), 2–50	4	3	3	4	2	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	7	.02
Arsenate of lead,[1] com. (3), 2–50	0	0	1	7	10	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	7	.12
Arsenate of calcium, c. p.[1] (powder), 1–50	0	1	1	4	3	5	3	3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	9	.13
Arsenate of iron, c. p.[1] (powder), 1–50	0	0	2	3	3	8	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	[2] 18	9	.39
Arsenate of iron, h. m.,[1] $\frac{8}{10}$–50	0	1	5	6	2	1	0	1	1	2	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	15	1.22
Arsenate of zinc, c. p.[1] (powder), 1–46	0	0	1	7	2	6	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	8	.15
Arsenate of zinc, h. m.,[1] $\frac{8}{10}$–50	2	1	4	1	6	4	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	8	.33
Arsenic sulphid, 1–54	1	1	0	5	9	0	3	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	9	.10
Arsenic tersulphid, ½–50	0	0	3	5	4	3	0	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	[2] 17	9	.007
Arsenic trioxid, ½–56	0	0	2	14	3	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	7	.06
Arsenite of lime,[1] h. m., 2 pts–50	1	1	2	2	1	1	4	5	3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	11	.22
Arsenite of zinc[1] (1), ½–43	0	0	3	5	5	6	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	8	.12
Arsenite of zinc[1] (2), 1½–50	0	1	8	3	5	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	[2] 19	7	.06
Arsenite of zinc[1] (3), ¾–50	0	0	1	1	2	6	9	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	9	.25
Arsenite of zinc[1] (4), ¾–50	0	0	2	3	3	3	2	3	2	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	13	.26
Barium chlorid, 6–50	0	0	0	1	0	0	0	0	0	5	3	2	5	3	1	....	....	....	....	....	....	....	....	....	....	20	23	2.52
Barium sulphate, 6–50	0	0	0	0	0	2	2	1	5	3	0	1	3	1	0	2	....	....	....	....	....	....	....	....	....	20	25	2.60
Calcium chlorid, 6–50	0	0	0	0	1	3	1	6	1	3	1	3	1	....	....	....	....	....	....	....	....	....	....	....	....	20	19	2.48
Copper oxid, 6–50	0	0	0	1	4	4	3	6	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	11	.68
Lead acetate, 6–50	0	0	1	2	4	3	1	0	1	1	0	0	1	1	2	....	....	....	....	....	....	....	....	....	....	[2] 17	23	1.33
Lead carbonate, 6–50	0	1	0	2	2	2	4	2	2	1	0	0	0	0	1	0	0	0	0	2	....	....	....	....	....	[2] 19	35	3.12
Lead chromate, 6–50	0	0	0	0	0	7	3	7	3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	11	.50
Lead oxid, 6–50	0	0	0	0	1	1	0	3	3	2	1	0	1	0	2	2	2	0	0	0	1	0	1	....	....	20	44	9.52
Lead peroxid, 6–50	0	0	0	0	0	0	1	2	1	0	1	2	2	4	1	3	3	....	....	....	....	....	....	....	....	20	27	14.70
Mercury bichlorid, ¾–50	0	0	0	0	1	1	3	3	3	3	0	0	2	0	0	0	0	3	0	0	1	....	....	....	....	20	37	5.41
Zinc chlorid, 3–50	0	0	0	0	10	8	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	9	.62
Zinc oxid, 6–50	0	0	0	0	1	3	3	2	2	0	1	0	2	2	0	3	0	0	0	1	....	....	....	....	....	20	35	7.00
Zinc sulphate, 6–50	0	0	0	0	0	3	0	0	2	0	0	0	1	2	1	1	1	1	3	1	0	0	2	....	....	[2] 18	44	8.63
Lime-sulphur, 1½–50	0	0	0	0	4	3	3	4	4	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	20	15	.73
Check (unsprayed) (1)	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	4	72	243.20
Check (unsprayed) (2)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	....	....	2	61	162.00

[1] Arsenate of lead, di.=diplumbic powder; tri.=triplumbic powder; di. and tri.=mixture of diplumbic and triplumbic powders; com. (1), (2), and (3)=commercial paste. Arsenite of zinc, (1)=chemically pure; (2)=paste, commercial; (3)=powder, commercial; (4)=powder, commercial. c. p.=chemically pure; h. m.=homemade.

[2] Remainder escaped.

Experiment III.

Comparison of the killing effect of various arsenicals on larvæ of the fall webworm.

In this experiment the same arsenicals were used as in Experiment I, all the other materials being omitted. However, since half-grown larvæ were used the strength of the materials was doubled. The results are shown in Table III.

Table III.—*Tests of the killing effect of various arsenicals on the fall webworm. Larvæ half grown.*

[Experiment started July 24, 1912, Benton Harbor, Mich.; 20 larvæ in each lot.]

Name and dilution.	Dates of examination and number of larvæ dying in each lot.									Total number dead.	Number days required to kill.	Square inches foliage consumed.
	July.					August.						
	26	27	28	29	31	2	4	7	12			
Arsenate of lead, di., 2–55	0	0	1	4	15	....	....	....	....	20	7	1.22
Arsenate of lead, tri., 2–42	0	0	0	1	1	7	8	3	....	20	14	.60
Arsenate of lead, di. and tri., 2–50	0	2	2	3	9	4	....	....	....	20	9	.43
Arsenate of lead, triplumbic, com. (1), 4–50	0	1	2	1	12	2	1	1	....	20	14	.84
Arsenate of lead, com. (2), 4–50	1	0	3	6	10	....	....	....	....	20	7	.94
Arsenate of lead, com. (3), 4–50	0	0	5	10	5	....	....	....	....	20	7	.37
Arsenate of calcium, c. p. (powder), 2–50	0	0	1	0	10	4	5	....	....	20	11	1.15
Arsenate of iron, c. p. (powder), 4–50	0	0	0	1	1	3	1	4	2	12	19	(2)
Arsenate of iron, h. m., $3\frac{2}{3}$–50	0	0	1	1	1	1	1	2	2	9	19	(2)
Arsenate of zinc, c. p. (powder), 2–46	4	0	0	5	11	....	....	....	....	20	7	2.03
Arsenate of zinc, h. m., $1\frac{6}{10}$–50	0	0	1	7	7	2	1	2	....	20	14	.87
Arsenic sulphid, 2–54	3	0	2	7	8	....	....	....	....	20	7	.95
Arsenic tersulphid, 1–50	4	1	3	5	3	4	....	....	....	20	9	.19
Arsenic trioxid, 1–56	5	6	4	0	3	1	....	....	....	[1] 19	9	.06
Arsenite of lime, 4 pts.–50	1	0	3	10	6	....	....	....	....	20	7	.56
Arsenite of zinc, c. p. (1), 2–43	3	0	2	9	4	....	....	....	....	[1] 18	7	.15
Arsenite of zinc, com. (2), 3–50	0	0	3	1	12	4	....	....	....	20	9	1.08
Arsenite of zinc, com. (3), $1\frac{1}{2}$–50	0	1	2	5	5	7	....	....	....	20	9	.94
Arsenite of zinc, com. (4), $1\frac{1}{2}$–50	0	0	1	3	9	6	....	....	....	[1] 19	9	.41
Check (unsprayed) (1)	0	0	0	0	0	0	0	0	0	0	19	(2)
Check (unsprayed) (2)	0	0	0	0	0	0	0	0	0	0	19	(2)

[1] Remainder escaped. [2] Not measured.

The results of these tests agree very well with the results obtained from Experiment I. The experiment was discontinued August 12, when all the larvæ were dead except in the case of arsenate of iron, chemically pure, where 8 larvæ still remained living, and arsenate of iron, homemade, where 11 remained living. All the larvæ on the unsprayed lots were alive at the time the experiment was closed.

Experiment IV.

Field tests of various arsenicals against the codling moth in Michigan, 1912.

Several arsenicals were tested in comparison with arsenate of lead against the codling moth in Mr. J. T. Beckwith's apple orchard in the vicinity of Benton Harbor. The trees were of the Ben Davis variety and about 35 years of age. The plats consisted of from 4 to 12 trees, and the fruit was counted from 3 trees of each plat. The extent of foliage injury from the various sprays was also noted. The homemade

preparations were prepared and diluted as given on page 2. The results against the codling moth are shown in Table IV.

TABLE IV.—*Sound and wormy apples from sprayed and unsprayed plats.*

[Poison test, Benton Harbor, Mich., 1912.]

Plat No.	Treatment.	Tree No.	Condition of fruit.			
			Wormy.	Sound.	Total.	Per cent sound.
I	Arsenate of lead (paste), 2 pounds to 50 gallons lime-sulphur solution	1	64	4,430	4,494	98.58
		2	14	1,542	1,556	99.10
		3	9	879	888	98.98
	Plat total	.....	**87**	**6,851**	**6,938**	**98.74**
II	Arsenate of lead (paste) commercial No. 1 (triplumbic), 2 pounds to 50 gallons lime-sulphur solution	1	33	874	907	96.36
		2	84	1,727	1,811	95.36
		3	44	1,115	1,159	96.20
	Plat total	.....	**161**	**3,716**	**3,877**	**95.85**
III	Arsenite of zinc (powder), ¾ pound to 50 gallons lime-sulphur solution	1	4	734	738	99.46
		2	20	1,110	1,130	98.23
		3	15	744	759	98.02
	Plat total	.....	**39**	**2,588**	**2,627**	**98.52**
IV	Arsenite of zinc (paste), 1½ pounds to 50 gallons lime-sulphur solution	1	19	1,387	1,406	98.65
		2	27	2,638	2,665	98.99
		3	7	486	493	98.58
	Plat total	.....	**53**	**4,511**	**4,564**	**98.83**
V	Arsenite of lime, homemade, 2 pints to 50 gallons lime-sulphur solution	1	32	680	712	95.50
		2	75	1,282	1,357	94.47
		3	52	1,201	1,253	95.85
	Plat total	.....	**159**	**3,163**	**3,322**	**95.21**
VI	Arsenate of zinc, homemade, at rate of 0.8 pound sodium arsenate to 50 gallons lime-sulphur solution	1	80	1,030	1,110	92.79
		2	261	1,597	1,858	85.95
		3	108	1,257	1,365	92.09
	Plat total	.....	**449**	**3,884**	**4,333**	**89.63**
VII	Arsenate of iron, c. p. (powder), ½ pound to 50 gallons lime-sulphur solution	1	174	942	1,116	84.41
		2	413	1,176	1,589	74.01
		3	254	1,228	1,482	82.86
	Plat total	.....	**841**	**3,346**	**4,187**	**79.91**
VIII	Arsenate of iron, homemade, at rate of 0.8 pound sodium arsenate to 50 gallons lime-sulphur solution	1	228	800	1,028	77.82
		2	205	970	1,175	82.55
		3	537	1,466	2,003	73.19
	Plat total	.....	**970**	**3,236**	**4,206**	**76.93**
IX	Arsenate of calcium, c. p. (powder), ½ pound to 50 gallons lime-sulphur solution	1	205	1,672	1,877	89.03
		2	95	529	624	84.77
		3	160	847	1,007	84.11
	Plat total	.....	**460**	**3,048**	**3,508**	**86.88**
X	Check (unsprayed)	1	257	231	488	47.33
		2	487	274	761	36.01
		3	744	445	1,189	37.43
	Plat total	.....	**1,488**	**950**	**2,438**	**38.96**

Arsenate of lead held the codling moth to 98.74 per cent of fruit free from worms, with no foliage injury resulting. Commercial arsenate of lead No. 1 (triplumbic) produced 95.85 per cent free from this insect, and the foliage was not injured. Arsenite of zinc powder and arsenite of zinc paste were as effective against the codling moth as arsenate of lead, but considerable foliage injury resulted from their use, about 50 per cent of the leaves being burned on these plats.

Arsenate of zinc, homemade, was effective, but fell somewhat below arsenate of lead in its efficiency. The foliage was not in the least injured from the use of this material.

Arsenates of iron, chemically pure and homemade, did not burn the foliage, but they were only moderately effective against the codling moth. As will be noted from the laboratory feeding tests with this material, its killing effect is slow.

Arsenate of calcium, chemically pure, 0.5 pound to 50 gallons, held the codling moth to 86.88 per cent of fruit free from injury. This fell somewhat below the efficiency of the standard arsenate of lead. However, the use of a slightly increased strength of this material would no doubt have been as effective as arsenate of lead, since it proved to be an effective poison in the laboratory feeding tests. Absolutely no burning resulted from its use, and its sticking qualities were excellent, as was indicated by the abundance of the material that could still be found on the foliage after several hard rains.

Only 38.96 per cent of the fruit from the three trees of the unsprayed plat was free from codling-moth injury.

Experiment V.

FOLIAGE INJURY TESTS OF VARIOUS ARSENICALS AND LIME-SULPHUR SOLUTION ON FOLIAGE OF PEACH AND BEAN.

A bean patch was planted in the laboratory yard, August 1, for the purpose of testing the burning effect of the various poisons used in the feeding tests. The leaves were sprayed with a large atomizer August 31. One row containing about 30 plants was used for each poison, one-third of the row being sprayed with the poison alone, one-third with the poison combined with lime at the strength of 2 pounds to 50 gallons of spray, and the remaining third with the poison combined with lime-sulphur, 1½ gallons to 50 gallons of spray. The spray was prevented from blowing to other parts of the row and to other rows by a canvas frame which was placed around the part being sprayed.

An experiment was also conducted on peach foliage on several trees in the laboratory yard. The poisons were used alone in all cases and were applied by means of an atomizer, using one peach limb for each poison. The spray was prevented from reaching other

parts of the tree by the use of a funnel-shaped canvas protector that was placed over the limb being sprayed.

The results of both bean and peach foliage tests are shown in Table V.

TABLE V.—*Tests of the effect of various arsenicals on foliage of bean and peach.*

[Experiment started Aug. 31, 1912, Benton Harbor, Mich. Foliage examined for two weeks.]

INJURY TO BEAN FOLIAGE.

Name and dilution.	Poison used alone.	Poison combined with lime, 2 to 50.	Poison combined with lime-sulphur, 1½ to 50.
Arsenate of lead, di. (powder), 1–50	No burning	No burning	No burning.
Arsenate of lead, tri. (powder), 1–50	do	do	Do.
Arsenate of lead, di. and tri. (powder), 1–50	do	do	Do.
Arsenate of lead, tri. com. paste (1), 2–50	do	do	Do.
Arsenate of lead, tri. com. paste (2), 2–50	Moderate burning	do	Do.
Arsenate of lead, tri. com. paste (3), 2–50	No burning	do	Do.
Arsenate of calcium, c. p. (powder), 1–50	do	do	Do.
Arsenate of iron, c. p. (powder), 2–50	do	do	Do.
Arsenate of iron, h. m., $\frac{8}{10}$–50	do	do	Do.
Arsenate of zinc, c. p. (powder), 1–50	do	do	Do.
Arsenate of zinc, h. m., $\frac{8}{10}$–50	do	do	Do.
Arsenic sulphid, 1–50	Severe burning	Severe burning	Severe burning.
Arsenic tersulphid, ½–50	do	do	Do.
Arsenic trioxid, ½–50	do	Slight burning	Do.
Arsenite of lime, h. m., 2 pts.–50	Moderate burning	No burning	Moderate burning.
Arsenite of zinc, powder (1) c. p., 1–50	Severe burning	do	Severe burning.
Arsenite of zinc (2), com. powder, ¾–50	Moderate burning	do	Moderate burning.
Arsenite of zinc (3), com. paste, 1½–50	do	do	Do.
Arsenite of zinc (4), com. powder, ¾–50	do	do	Do.
Paris green, ½–50	do	Moderate burning	Do.
Lime-sulphur, 1½–50	No burning		

INJURY TO PEACH FOLIAGE.

Name and dilution.	Poison used alone.
Aresenate of lead, di. (powder), 1–50	Very slight burning.
Arsenate of lead, tri. (powder), 1–50	No burning.
Arsenate of lead, di. and tri. (powder), 1–50	Slight burning.
Arsenate of lead, tri. com. paste (1), 2–50	No burning.
Arsenate of lead, tri. com. paste (2), 2–50	Severe burning.
Arsenate of lead, tri. com. paste (3), 2–50	Very slight burning.
Arsenate of calcium, c. p. (powder), 1–50	Moderate burning.
Arsenate of iron, c. p. (powder), 2–50	No burning.
Arsenate of iron, h. m., $\frac{8}{10}$–50	Do.
Arsenate of zinc, c. p. (powder), 1–50	Severe burning.
Arsenate of zinc, h. m., $\frac{8}{10}$–50	Very slight burning.
Arsenic sulphid, 1–50	Severe burning.
Arsenic tersulphid, ½–50	Do.
Arsenic trioxid, ½–50	Do.
Arsenite of lime, h. m., 2 pts.–50	Do.
Arsenite of zinc, powder (1), c. p., 1–50	Do.
Arsenite of zinc (2), com. powder, ¾–50	Do.
Arsenite of zinc (3), com. paste, 1½–50	Do.
Arsenite of zinc (4), com. powder, ¾–50	Do.
Paris green, ½–50	Do.
Lime-sulphur, 1½–50	

Of the arsenates of lead, the diplumbic form had no burning effect on bean foliage and burned peach foliage very slightly. Arsenate of lead, consisting of a mixture of the diplumbic and triplumbic forms, burned peach foliage slightly, but no injury resulted on bean foliage. The commercial No. 1, consisting of the triplumbic form of arsenate of lead, did not injure peach or bean foliage. The commercial (2) burned the peach so badly that all the leaves were shed, and produced

moderate burning on the bean, about 25 per cent of the leaves being shed, but no burning where it was combined with lime or lime-sulphur. The commercial (3) produced no burning on bean foliage and very slight burning on peach foliage.

Arsenate of calcium, c. p., caused about 15 per cent of the leaves to drop on peach, but had no burning effect on bean foliage.

The arsenates of iron, chemically pure and homemade, did not burn either bean or peach foliage.

Arsenate of zinc, c. p., did not burn bean foliage, but seriously injured peach foliage, causing complete defoliation. The homemade form of arsenate of zinc produced very slight burning on peach and no burning on bean foliage.

Arsenic sulphid produced severe burning in all tests.

Arsenic tersulphid produced the same results as arsenic sulphid.

Arsenic trioxid burned severely in all cases except when combined with lime, in which case the burning was slightly less.

Arsenite of lime, homemade, burned the bean foliage moderately when used alone and in combination with lime-sulphur. However, no burning resulted when extra lime was added. The peach foliage was severely burned by this material, causing all the leaves to drop.

Arsenite of zinc (1), chemically pure, burned severely in all cases except where lime was used, in which case no burning resulted.

Arsenite of zinc powder, commercial (2), burned moderately on beans except where lime was added, in which case no burning resulted. It caused all of the peach leaves to drop. Arsenite of zinc, commercial (3) and commercial (4), gave the same results.

Paris green produced moderate burning in all the tests on bean foliage and burned all the leaves off the peach.

EXPERIMENTS, 1913.

LABORATORY TESTS.

Several poisons, namely, arsenate of lead paste, commercial; two commercial brands of powdered arsenate of lead; arsenate of calcium, commercial; two forms of arsenate of calcium, homemade; arsenate of zinc, homemade, and arsenite of zinc, homemade, were tested against the larvæ of several different species of chewing insects.

The arsenates of lead and the arsenite of zinc were used at the strengths recommended by the manufacturers. Arsenate of calcium, commercial paste, was used at the rate of 1⅓ pounds to 50 gallons of water. Arsenate of zinc, homemade, was prepared and used as given on page 2. Arsenate of calcium (1) was prepared by dissolving 1 pound of sodium arsenate and 1 pound of calcium acetate each in 1 gallon of hot water and pouring them together slowly, at the same time stirring the solution vigorously. This was used at a strength equivalent to 0.8 pound of sodium arsenate to 50 gallons of

water. Arsenate of calcium, homemade (2), was prepared from sodium arsenate and calcium chlorid, the method of procedure being the same as for arsenate of calcium, homemade (1), and was used at the same strength.

Lead chromate, commercial, was used at the rate of 8 pounds to 50 gallons. Lead chromate, homemade, was prepared by dissolving 2 ounces of lead nitrate in one lot of water and 1 ounce of potassium bichromate in another lot of water. The two solutions were then mixed, and a dense yellow precipitate of insoluble lead chromate was formed. The amount of lead chromate formed is 2 ounces, and the strengths at which the material was used in these experiments were based on the amount of lead chromate formed.

H. Maxwell-Lefroy and R. S. Finlow state the following in regard to the use of the above form of homemade lead chromate as an insecticide:[1]

> During this year we have applied this compound to a great variety of crops. We have sprayed them till every leaf was yellow. The poison has remained on for over three weeks, thickly on the leaves, which were uninjured. Sprayed on to crops attacked by caterpillars, the caterpillars are killed, and the results obtained have been excellent. We have used this at 1 pound in 32 gallons. At this strength it is entirely safe, poisons caterpillars, and acts as a very powerful deterrent. * * * Lead chromate has not the poisoning effect of Paris green, for instance, which can be applied at 1 pound in 200 gallons, but it has a poisoning effect comparable with that of lead arsenate, and is, in our experience, a perfect substitute.

As a result of this success with the use of this preparation as an insecticide in India, thorough tests were made with it in experiments conducted during the season of 1913.

Experiment VI.

Arsenate of lead versus arsenate of calcium against larvæ of the tent caterpillar.

In this experiment arsenate of lead paste and the different forms of arsenate of calcium were tested in comparison against newly hatched larvæ of the tent caterpillar. The results of this test are shown in Table VI.

Arsenate of lead alone killed the 50 larvæ in each of the two lots in 5 days, with 0.04 square inch of foliage consumed. Combined with lime-sulphur it required 2 days longer to kill, but only 0.01 square inch of foliage was consumed.

Arsenate of calcium, homemade (1), prepared from sodium arsenate and calcium acetate, killed the larvæ in 5 to 7 days, with 0.05 and 0.06 square inch of foliage consumed when used alone, and in 5 days when combined with lime-sulphur, with 0.02 square inch of foliage consumed. Arsenate of calcium, homemade (2), gave practically the same results.

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[1] Maxwell-Lefroy, H., and Finlow, R. S. Inquiry into the insecticidal action of some mineral and other compounds on caterpillars. *In* Memoirs Dept. Agr. India, Ent. Ser., v. 4, no. 5, p. 269–327, 1913.

TABLE VI.—*Tests of the killing effect on the tent caterpillar of arsenate of calcium, alone and combined with lime-sulphur, in comparison with arsenate of lead.*

[Experiment started May 17, 1913, Benton Harbor, Mich.; 50 larvæ in each lot.]

Dates of examination.	Check (unsprayed).		Larvæ dying in each lot.											
			Arsenate of lead, 2 to 50.			Arsenate of calcium (homemade, 1), 0.8 lb. to 50.			Arsenate of calcium (homemade, 2), 0.8 lb. to 50.			Arsenate of calcium (commercial paste), 1⅓ to 50.		
			Alone.		With lime-sulphur, 1½ to 50.	Alone.		With lime-sulphur, 1½ to 50.	Alone.		With lime-sulphur, 1½ to 50.	Alone.		With lime-sulphur, 1½ to 50.
	Lot 1.	Lot 2.	Lot 3.	Lot 4.	Lot 5.	Lot 6.	Lot 7.	Lot 8.	Lot 9.	Lot 10.	Lot 11.	Lot 12.	Lot 13.	Lot 14.
May 20	1	1	42	45	16	36	38	27	30	33	20	35	43	28
May 22	2	1	8	5	27	12	12	23	18	17	20	15	7	18
May 24	1	0	.....	.....	7	2	.....	.....	2	.....	10	.....	.....	4
May 31	0	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Total number dead	4	2	50	50	50	50	50	50	50	50	50	50	50	50
Days required to kill	.....	.....	5	5	7	7	5	5	7	5	7	5	5	7
Square inches foliage consumed	8.10	6.75	0.04	0.04	0.01	0.05	0.06	0.02	0.04	0.06	0.02	0.06	0.05	0.03

Arsenate of calcium, commercial (paste), used at the rate of 1⅓ pounds to 50 gallons killed all the larvæ in 5 days with 0.05 and 0.06 square inch of foliage consumed. The same preparation combined with lime-sulphur killed in 7 days with 0.03 square inch of foliage consumed.

It will be noted that when lime-sulphur was used with the poison, less foliage was consumed.

EXPERIMENT VII.

LEAD CHROMATE VERSUS ARSENATE OF LEAD AGAINST THE LARVÆ OF FOUR SPECIES OF INSECTS.

Experiments were conducted with lead chromate, commercial and homemade, used at various strengths in comparison with arsenate of lead used at the rate of 2 pounds to 50 gallons of water, against four species of insects, *Eriocampoides cerasi* Peck, *Hyphantria cunea*, *Halisidota caryae* Harris, and *Datana ministra* Drury. The results of these experiments are given in Table VII.

Neither the commercial nor homemade lead chromate was very effective against the pear slug (*Eriocampoides cerasi*), 6 larvæ living through to pupation in each case, and almost as much foliage was consumed as on one of the checks. Arsenate of lead killed 8 of the larvæ in 3 days. The other 2 larvæ escaped. Nine of the larvæ pupated in each of the two unsprayed lots.

TABLE VII.—*Tests of the killing effect on four species of insects of commercial and home-made lead chromate in comparison with arsenate of lead.*

[Benton Harbor, Mich., 1913.]

Name of insect.	Number of larvæ.	Name of material and dilution.	Date experiment started.	Date experiment closed.	Number of observations.	Total larvæ dead.	Number days required to kill.	Square inches foliage consumed.
Eriocampoides cerasi...	10	Check (unsprayed).....	July 2	July 7	5	[1] 1	.....	9.64
	10	.....do.....	...do....	...do....	5	[1] 1	.....	4.36
	10	Arsenate of lead, commercial, 2–50.	...do....	July 5	3	[2] 8	3	0.25
	10	Lead chromate, commercial, 2–50.	...do....	July 7	5	[1] 4	.....	3.48
	10	Lead chromate, homemade, ¾–50.	...do....	...do....	5	[1] 4	.....	3.39
Hyphantria cunea.....	20	Check (unsprayed).....	July 14	July 31	9	4	.....	41.00
	20	.....do.....	...do....	...do....	9	4	.....	37.00
	20	Arsenate of lead, commercial, 2–50.	...do....	July 18	2	20	4	.08
	20	.....do.....	...do....	...do....	2	20	4	.14
	20	Lead chromate, commercial, 8–50.	...do....	July 21	4	20	7	.96
	20	.....do.....	...do....	...do....	4	20	7	.72
	20	Lead chromate, homemade, 1½–50.	...do....	July 23	5	20	9	1.04
	20	.....do.....	...do....	July 21	4	20	7	.88
Halisidota caryæ.....	20	Check (unsprayed).....	...do....	Aug. 1	9	1	.....	3.50
	20	.....do.....	...do....	...do....	9	1	.....	2.20
	20	Arsenate of lead, commercial, 2–50.	...do....	July 18	2	20	4	.30
	20	.....do.....	...do....	...do....	2	20	4	.50
	20	Lead chromate, commercial, 2–50.	...do....	Aug. 1	9	1	.....	3.25
	20	.....do.....	...do....	...do....	9	3	.....	3.50
	20	Lead chromate, homemade, ¾–50.	...do....	...do....	9	1	.....	1.50
	20	.....do.....	...do....	...do....	9	0	.....	1.60
Datana ministra.....	20	Check (unsprayed).....	Aug. 8	Aug. 14	6	1	.....	.....
	20	Arsenate of lead, commercial, 2–50.	...do....	Aug. 10	2	20	2	.....
	20	Lead chromate, commercial, 8–50.	...do....	...do....	2	20	2	.....
	20	Lead chromate, homemade, ¾–50.	...do....	Aug. 14	6	20	6	.....
	20	Lead chromate, homemade, 1½–50.	...do....	Aug. 13	5	20	5	.....
	20	Lead chromate, homemade, 3–50.	...do....	Aug. 10	2	20	2	.....

[1] Remainder pupated. [2] Remainder escaped.

Against the fall webworm (*Hyphantria cunea*) lead chromate, used at the rate of 8 pounds to 50 gallons of water, was effective, although 3 more days were required to kill in this case than in the case of arsenate of lead used at the rate of 2 pounds to 50 gallons of water. The strength of lead chromate in this case is four times greater than was used against the pear slug. Lead chromate, home-made, was used at the rate of 1½ pounds to 50 gallons of water, twice the strength that was used against the pear slug. All the larvæ were killed in 7 to 9 days, which was considerably slower than with arsenate of lead, and considerably more foliage was consumed. Four of the larvæ were dead in each lot of the checks at the end of the experiment, which was closed July 31.

The experiment against *Halisidota caryae* ran for 18 days, at the end of which time the lead chromate, commercial and homemade,

used at the weaker strengths, apparently had no effect on the larvæ. The arsenate of lead killed all the larvæ in 4 days.

For the *Datana ministra*, the commercial lead chromate was used at the rate of 8 pounds to 50 gallons of water, and at this strength the killing effect of the material compared favorably with that of arsenate of lead, 2 pounds to 50 gallons. The lead chromate, homemade, was used at three strengths—¾, 1½, and 3 pounds to 50 gallons of water. The weakest strength killed all the larvæ in 6 days, the next stronger in 5 days. Only one larva had died in the unsprayed lot at the time the experiment was closed, August 14.

Experiment VIII.

COMPARISON OF THE KILLING EFFECT OF ARSENATE OF LEAD, ARSENATE OF CALCIUM, ARSENATE OF ZINC, ARSENITE OF ZINC, AND LEAD CHROMATE ON LARVÆ OF THE FALL WEBWORM.

Different forms of arsenate of lead, arsenate of calcium, and lead chromate were tested against the larvæ of the fall webworm (*Hyphantria cunea*). Arsenate of zinc and arsenite of zinc were also included in this test, as shown in Table VIII.

Table VIII.—*Tests of the killing effect of various materials on the fall webworm.*

[Experiment started July 23, 1913, Benton Harbor, Mich.; 20 larvæ in each lot.]

Lot No.	Name and dilution.	Dates of examination and number of larvæ dying in each lot.												Total number dead.	Number days required to kill.	Square inches foliage consumed.
		July.								August.						
		24	25	26	27	28	29	30	31	1	2	3	4			
1	Arsenate of lead paste, commercial, 2–50	0	0	0	0	4	9	7	....	....	....	....	....	20	7	0.42
2	.....do	0	1	1	1	10	6	1	....	....	....	....	....	20	7	.24
3	Arsenate of lead powder, commercial (1), 1–50	0	0	0	0	4	9	7	....	....	....	....	....	20	7	.41
4	.....do	0	0	2	2	10	4	2	....	....	....	....	....	20	7	.22
5	Arsenate of lead powder, commercial (2), 1–50	0	0	1	5	7	7	....	....	....	....	....	....	20	6	.13
6	.....do	0	0	2	1	6	9	2	....	....	....	....	....	20	7	.24
7	Arsenate of calcium paste, commercial, 1⅓–50	0	1	0	1	10	1	5	2	....	....	....	....	20	8	.75
8	.....do	0	1	1	2	5	3	5	3	....	....	....	....	20	8	.88
9	Arsenate of calcium, homemade (1), $\frac{8}{10}$–50	0	0	0	7	11	2	....	....	....	....	....	....	20	6	.15
10	.....do	0	0	1	3	15	1	....	....	....	....	....	....	20	6	.17
11	Arsenate of calcium, homemade (2), $\frac{8}{10}$–50	0	0	2	2	12	2	2	....	....	....	....	....	20	7	.19
12	.....do	0	0	1	2	12	3	2	....	....	....	....	....	20	7	.12
13	Arsenate of zinc, homemade, $\frac{8}{10}$–50	0	0	0	1	18	1	....	....	....	....	....	....	20	6	.29
14	.....do	0	0	0	1	16	3	....	....	....	....	....	....	20	6	.20
15	Arsenite of zinc powder, commercial, ¾–50	0	1	2	7	3	2	4	1	....	....	....	....	20	8	.50
16	.....do	0	1	0	2	8	5	1	3	....	....	....	....	20	8	.79
17	Lead chromate powder, commercial, 8–50	0	0	0	0	1	9	8	2	....	....	....	....	20	8	.84
18	.....do	0	0	0	0	0	5	5	7	1	1	1	....	20	11	2.01
19	Lead chromate, homemade, 1½–50	0	0	0	0	1	6	8	1	2	2	....	....	20	10	1.70
20	.....do	0	0	0	0	0	4	6	1	3	4	1	1	20	12	2.09
21	Check (unsprayed)	0	0	0	0	0	0	0	1	0	0	2	0	3	.....	20.17
22	.....do	0	0	0	0	0	0	0	0	0	0	1	0	1	.....	20.56

Seven days were required to kill the 20 larvæ by arsenate of lead paste, and the two powder forms of arsenate of lead gave almost identical results. Arsenate of calcium, commercial, was one day slower in killing, and slightly more foliage was consumed where this material was used. The two forms of arsenate of calcium, homemade, killed in 6 and 7 days, comparing favorably with the arsenates of lead both in the length of time required to kill and in the amount of foliage consumed. Arsenate of zinc, homemade, killed in 6 days, with 0.20 to 0.29 square inch of foliage consumed. Arsenite of zinc, commercial, required 8 days to kill all the larvæ and 0.79 to 0.84 square inch of foliage was consumed. Lead chromate used at increased strengths was again slow in its killing effect, and more foliage was consumed than in the case of the arsenates. Three larvæ in one lot and one larva in the other lot of unsprayed were dead at the time the experiment was closed August 4. On the two checks 20.17 and 20.56 square inches of foliage were consumed, respectively.

Experiment IX.

COMPARISON OF THE KILLING EFFECT OF ARSENATE OF LEAD, ARSENATE OF CALCIUM, ARSENATE OF ZINC, ARSENITE OF ZINC, AND LEAD CHROMATE ON LARVÆ OF THE TUSSOCK MOTH.

Three forms of arsenate of lead, three forms of arsenate of calcium, lead chromate (commercial), arsenate of zinc, and arsenite of zinc were tested against larvæ of the tussock moth (*Hemerocampa leucostigma* S. and A.). The experiment was started June 26 and closed July 6, when all the larvæ were dead except in the unsprayed lots. Table IX gives the results of this test.

The three forms of arsenate of lead killed in 4 days, except in one lot of the paste form which required 6 days to kill; the amount of foliage consumed for all the forms varying from 0.01 to 0.08 square inch. Arsenate of calcium, commercial, required on an average more than twice as long to kill as required by arsenate of lead, and considerably more foliage was consumed. The two forms of arsenate of calcium, homemade, killed in slightly less time than was required by the commercial form. Lead chromate, commercial, used at the strength of 8 pounds to 50 gallons of water killed in 6 to 8 days, which was a longer time than required by the ordinary strength of arsenate of lead. Arsenate of zinc, homemade, and arsenite of zinc, commercial, were slower in their killing effect on this insect than was arsenate of lead. Three larvæ were dead in each of two lots of the unsprayed and four dead in the remaining lot, and 5.55 to 7.20 square inches of foliage had been consumed at the time the experiment was closed.

TABLE IX.—*Tests of the killing effect of various poisons on the tussock moth.*

[Experiment started June 26, 1913, Benton Harbor, Mich.; 25 larvæ in each lot.]

Lot No.	Name and dilution.	Dates of examination and larvæ dying in each lot.					Total number dead.	Number days required to kill.	Square inches foliage consumed.
		June.		July.					
		28	30	2	4	6			
1	Arsenate of lead paste, commercial, 2-50	13	12	....	....	....	25	4	0.06
2	.....do	15	10	....	....	....	25	4	.01
3	.....do	11	11	3	....	....	25	6	.08
4	Arsenate of lead powder, commercial (1), 1-50	13	12	....	....	....	25	4	.01
5	.....do	7	18	....	....	....	25	4	.05
6	.....do	18	7	....	....	....	25	4	.02
7	Arsenate of lead powder, commercial (2), 1-50	10	15	....	....	....	25	4	.07
8	.....do	16	9	....	....	....	25	4	.04
9	.....do	17	8	....	....	....	25	4	.02
10	Arsenate of calcium paste, commercial, 1½-50	4	11	1	5	4	25	10	.50
11	.....do	2	3	7	13	....	25	8	.68
12	.....do	5	8	10	2	....	25	8	.42
13	Arsenate of calcium, homemade (1), 0.8-50	9	7	4	2	3	25	10	.20
14	.....do	10	7	4	4	....	25	8	.38
15	.....do	6	15	4	....	....	25	6	.15
16	Arsenate of calcium, homemade (2), 0.8-50	10	6	1	0	5	25	10	.10
17	.....do	4	17	3	1	....	25	8	.23
18	.....do	17	7	1	....	....	25	6	.06
19	Lead chromate, commercial, 8-50	0	9	16	....	....	25	6	.55
20	.....do	0	6	16	3	....	25	8	.20
21	.....do	0	5	20	....	....	25	6	.18
22	Arsenate of zinc, homemade, 0.8-50	10	10	1	4	....	25	8	.46
23	.....do	12	9	1	3	....	25	8	.38
24	.....do	5	15	0	5	....	25	8	.62
25	Arsenite of zinc powder, commercial, ¾-50	8	15	0	1	1	25	10	.60
26	.....do	6	9	8	2	....	25	8	.74
27	.....do	8	8	3	6	....	25	8	.72
28	Check (unsprayed)	0	1	0	0	2	3	.....	5.80
29	.....do	0	0	0	3	0	3	.....	7.20
30	.....do	0	2	0	2	0	4	.....	5.55

EXPERIMENT X.

FIELD TESTS OF VARIOUS ARSENICALS AGAINST THE CODLING MOTH, 1913.

Field tests were made with the following preparations against the codling moth on apple: Arsenate of lead paste, commercial; arsenate of calcium paste, commercial; arsenate of calcium, homemade, prepared from sodium arsenate and calcium acetate; arsenate of calcium, homemade, prepared from sodium arsenate and calcium chlorid; arsenite of zinc powder, commercial; and arsenate of zinc, homemade. (For methods of preparation of the homemade materials, see p. 2.) All the materials were used in combination with lime-sulphur, 1½ to 50. The spraying was done in Mr. J. T. Beckwith's orchard in the vicinity of Benton Harbor, Mich., the same orchard that was used for the experimental work of the previous season. The results of this experiment are shown in Table X.

TABLE X.—*Sound and wormy apples from sprayed and unsprayed plats.*

[Poison test, Benton Harbor, Mich., 1913.]

Plat No.	Treatment.	Tree No.	Condition of fruit.			
			Wormy.	Sound.	Total.	Per cent sound.
I	Arsenate of lead (paste), 2 pounds to 50 gallons of lime-sulphur solution	1	129	2,144	2,273	94.32
		2	132	2,490	2,622	94.96
		3	135	2,244	2,379	94.32
		4	157	1,850	2,007	92.17
		5	125	1,927	2,052	93.90
	Plat total		**678**	**10,655**	**11,333**	**94.01**
II	Arsenate of calcium, homemade (1), at rate of 8/10 pound sodium arsenate to 50 gallons lime-sulphur solution	1	398	2,767	3,165	87.42
		2	208	1,443	1,651	87.40
		3	180	740	920	80.43
		4	254	720	974	73.92
		5	331	976	1,307	74.67
	Plat total		**1,371**	**6,646**	**8,017**	**82.89**
III	Arsenate of calcium, homemade (2), at rate of 8/10 pound sodium arsenate to 50 gallons lime-sulphur solution	1	580	2,607	3,187	81.80
		2	388	897	1,285	69.80
		3	497	1,195	1,692	70.62
		4	387	955	1,342	71.16
		5	260	600	860	69.76
	Plat total		**2,112**	**6,254**	**8,366**	**74.75**
IV	Arsenate of calcium, commercial (paste), 1⅓ pounds to 50 gallons lime-sulphur solution	1	251	813	1,064	76.41
		2	241	918	1,159	79.20
		3	53	277	330	83.94
		4	240	681	921	73.94
		5	303	1,025	1,328	77.18
	Plat total		**1,088**	**3,714**	**4,802**	**77.34**
V	Arsenite of zinc powder, ¾ pound to 50 gallons lime-sulphur solution	1	241	2,345	2,586	90.68
		2	83	978	1,061	92.17
	Plat total		**324**	**3,323**	**3,647**	**91.11**
VI	Arsenate of zinc, homemade, at rate of 8/10 pound sodium arsenate to 50 gallons lime-sulphur solution	1	365	2,342	2,707	86.51
		2	503	1,867	2,370	78.78
		3	376	1,731	2,107	82.15
		4	213	1,386	1,599	86.68
		5	186	1,951	2,137	91.92
	Plat total		**1,643**	**9,277**	**10,920**	**84.95**
VII	Check (unsprayed)	1	927	877	1,804	48.61
		2	670	503	1,173	42.88
		3	1,082	1,086	2,168	50.01
		4	606	592	1,198	49.41
		5	933	780	1,713	45.53
	Plat total		**4,218**	**3,838**	**8,056**	**47.64**

The arsenate of lead plat produced 94.01 per cent of fruit free from codling-moth injury. Arsenate of calcium, homemade (1), fell below this in its efficiency, the percentage of sound fruit being 82.89. Arsenate of calcium, homemade (2), fell still lower in efficiency, producing 74.75 per cent of fruit free from this insect. Each of these materials burned the foliage very slightly. Arsenate

of calcium, commercial, produced 77.34 per cent of sound fruit, about an average of the efficiency of the two homemade preparations. The slight burning effect on the foliage amounted to about the same as on the homemade arsenate of calcium plats. Arsenite of zinc powder, commercial, produced 91.11 per cent sound fruit. This material produced moderate burning, about 20 per cent of the leaves being more or less spotted by the spray. Arsenate of zinc, homemade, produced no burning of the foliage and held the codling moth to 84.95 per cent free from worms. The unsprayed plat averaged 47.64 per cent of fruit free from codling-moth injury.

EXPERIMENTS, 1914.

Experiments with various insecticides, alone and combined with fungicides, were made, both at the laboratory and in the field, during the season of 1914. The investigations were continued along the same lines as during the two previous seasons.

The field experiments were conducted in the J. T. Beckwith apple orchard, the John Hamilton pear orchard, both of Benton Harbor, Mich., and the William Birkit vineyard, located at Glenlord, Mich. The field experiments were on a relatively large scale, so that the results represent what may be expected on a commercial basis.

LABORATORY TESTS.

The fall webworm (*Hyphantria cunea* Drury) was not so abundant as during the seasons of 1912 and 1913, and it was not always possible to secure a sufficient number of young larvæ for the poison-feeding tests. Consequently, when larger larvæ were used, the strength of the poisons was increased to accelerate the killing of the larvæ. However, the same size of larva was used in all lots in each experiment, and the results are therefore comparative.

The laboratory experiments included commercial and homemade insecticides, used alone or combined with a fungicide. Wild-cherry twigs were sprayed by means of a hand atomizer and the spray material allowed to dry thoroughly before placing the larvæ upon the host plant. Time did not permit daily observations, and accordingly the results do not always represent close comparisons, but from a practical point of view they are sufficient.

Experiment XI.

VARIOUS ARSENICALS ALONE AND COMBINED WITH OIL EMULSIONS AGAINST LARVÆ OF THE FALL WEBWORM.

The chief object of this experiment was to ascertain whether the combining of arsenate of lead with kerosene emulsion would affect the individual value of either material for insecticidal purposes.

Other arsenicals, namely, commercial arsenite of zinc and commercial arsenate of calcium, were likewise tested. The results are given in Table XI.

TABLE XI.—*Tests of the killing effect of various materials on the fall webworm.*

[Experiment started July 17, 1914, Benton Harbor, Mich.; 10 larvæ in each lot.]

Lot No.	Name and dilution.	Dates of examination and number of larvæ dying in each lot.				Total number dead.	Number days required to kill.	Square inches foliage consumed.
		July.		August.				
		23	29	7	13			
1	Kerosene emulsion, 10 per cent	0	0	0	0	0	.....	61.00
2	Arsenate of lead powder, 1½–50 + kerosene emulsion, 10 per cent.	10	....	....	....	10	6	0.36
3	Arsenite of zinc powder, 1⅛–50+kerosene emusion, 10 per cent.	10	....	....	....	10	6	0.20
4	Arsenate of calcium, commercial powder, 1½–50+kerosene emulsion, 10 per cent	0	3	6	1	10	27	13.50
5	Anthracene emulsion, 10 per cent	[1]10	....	....	....	10	6	0.01
6	Arsenate of lead powder, 1½–50+anthracene emulsion, 10 per cent	[1]10	....	....	....	10	6	0.01
7	Arsenate of lead powder, 1½–50	[1]0	....	....	....	10	6	0.14
8	Arsenite of zinc powder, 1⅛–50	10	....	....	....	10	6	0.04
9	Arsenate of calcium, commercial powder, 1½–50	10	....	....	....	10	6	0.48
10	Check (unsprayed)	0	0	0	0	0	.....	53.00

[1] Foliage badly burned—unfit for consumption.

Kerosene emulsion alone, at a 10 per cent strength, had no poisonous effect upon the fall webworm larvæ—at least none had been killed after having fed for a period of 27 days, with a consumption of 61 square inches of foliage. The arsenate of lead alone killed the 10 larvæ in 6 days—foliage consumed, 0.14 square inch. A combination of these insecticides also caused the death of all the larvæ in 6 days after 0.36 square inch of foliage had been eaten. The other arsenicals, alone or combined with the emulsion (except arsenate of calcium combined), likewise killed in 6 days after a relatively small amount of foliage had been consumed. Arsenate of calcium powder, used alone, was quite as effective as the other arsenicals, but in combination with the emulsion 27 days were required to kill the larvæ, which consumed 13.50 square inches of foliage. A similar result was obtained in a later experiment. (See Experiment XIII.) Anthracene emulsion, 10 per cent, alone and combined with arsenate of lead, burned the foliage badly, rendering it unpalatable.

As shown in Experiment XV, kerosene emulsion, 10 per cent, combined with arsenate of lead is also an effective aphidicide. Although there is some breaking down of the materials in combination, no injury to the foliage was noted in the laboratory tests.

Experiment XII.

Combined sprays against larvæ of the fall webworm.

The purpose of Experiment XII was to test by the laboratory method certain spray combinations, some of which were being used under field conditions. The arsenate of calcium used in this experiment was prepared by using 4 pounds of stone lime, to which was added 18 ounces of sodium-arsenate crystals during the slaking. This, when mixed with the proper quantity of water, was used for the making of Bordeaux mixture 4–4–50. This combination was made with a view to using it as a vineyard spray. The results of this experiment appear in Table XII.

Table XII.—*Tests of the killing effect of various materials on the fall webworm.*

[Experiment started July 24, 1914, Benton Harbor, Mich.; 10 larvæ in each lot.]

Lot No.	Name and dilution.	Dates of examination and number of larvæ dying in each lot.				Total number dead.	Number days required to kill.	Square inches foliage consumed.
		July.		August.				
		29	1	7	13			
1	Arsenate of lead powder, 1½–50+lime-sulphur, 1½–50	7	3	....	....	10	8	0.18
2	Lime-sulphur, 1½–50	5	1	4	....	10	14	0.82
3	Arsenate of lead powder, 1½–50	7	3	....	....	10	8	0.46
4	Commercial sodium sulphid, 2–50	2	4	3	1	10	20	3.34
5	Commercial sodium sulphid, 2–50+arsenate of lead powder, 1½–50	7	3	....	....	10	8	0.22
6	Commercial barium tetrasulphid, 5–50	4	0	5	1	10	20	5.76
7	Commercial barium tetrasulphid, 5–50+arsenate of lead powder, 1½–50	3	6	1	....	10	14	0.34
8	Sodium arsenate (crystals, tech. pure), 18 ounces+Bordeaux mixture, 4–4–50	8	2	....	....	10	8	0.10
9	Sodium arsenate (crystals, tech. pure), 18 ounces+Bordeaux mixture, 4–4–50+nicotine sulphate, 40 per cent, 1–1,600	5	5	....	....	10	8	0.10
10	Check (unsprayed)	1	1	0	0	2	.....	13.50

As will be noted in Table XII, arsenate of lead, either alone or combined with lime-sulphur solution or commercial sodium sulphid, killed all the larvæ in 8 days. The same arsenical combined with commercial barium tetrasulphid compound required 14 days to kill the 10 larvæ, although 9 of these were recorded dead at the end of the eighth day. The arsenate of calcium made in the same operation of slaking the stone lime for Bordeaux mixture caused the death of all the larvæ in 9 days. This combination was tested in a vineyard and caused no foliage injury. At the end of 20 days, when the experiment was closed, but two larvæ of the unsprayed lot were dead.

Experiment XIII.

ARSENATE OF CALCIUM VERSUS ARSENATE OF LEAD, ALONE AND COMBINED WITH KEROSENE EMULSION AND WITH LIME-SULPHUR SOLUTION AGAINST LARVÆ OF THE FALL WEBWORM.

In this experiment a comparative test was made with homemade arsenate of calcium at several strengths, commercial arsenate of calcium, paste and powder, and other materials.

The homemade arsenate of calcium used in this and succeeding experiments was prepared by adding sodium-arsenate crystals to stone lime during the course of slaking.

Formula 1.—Stone lime, 1 pound; sodium arsenate, ½ pound; water, 1½ quarts. This formula, according to chemical analysis, gave a total arsenic oxid (As_2O_5) content of 4.19 per cent; no soluble arsenic oxid.

Formula 2.—Stone lime, 3 pounds; sodium arsenate, 3 pounds; water, 4 quarts; analysis—total arsenic oxid (As_2O_5), 6.16 per cent, no soluble arsenic oxid.

Formula 3.—Stone lime, 4 pounds; sodium arsenate, 2 pounds; water, 4 quarts; analysis—total arsenic oxid (As_2O_5), 3.93 per cent; no soluble arsenic oxid.

Formula 4.—Stone lime, 4 pounds; sodium arsenate, 1 pound; water, 5 quarts; analysis—total arsenic oxid (As_2O_5), 1.88 per cent; no soluble arsenic oxid.

Formula 5.—Stone lime, 3 pounds; sodium arsenate, 1 pound; water, 3 quarts; analysis—total arsenic oxid (As_2O_5), 2.92 per cent; no soluble arsenic oxid.

Formula 6.—Stone lime, 4 pounds; sodium arsenate, 2 pounds; water, 4 quarts; slaking not vigorous; not analyzed.

In all of the homemade formulas lime has been used in considerable excess, with a corresponding decrease of the arsenical content. The commercial arsenate of calcium, paste, showed an analysis of 18.82 per cent total arsenic oxid—soluble arsenic oxid, a trace.

With a view to making a combination spray for peaches and other stone fruits, arsenate of calcium was prepared in the same operation with the making of self-boiled lime-sulphur (8–8–50 formula). As soon as the lime started to slake, 2 pounds of sodium-arsenate crystals and then the sulphur were added and the mixture made up in the usual way. Arsenate of calcium made with self-boiled lime-sulphur may be of value as a spray for stone fruits, owing to the fact that the large excess of lime would tend to prevent burning. Arsenate of calcium, alone, causes injury to peach foliage, unless there is an excess of lime. The calcium on exposure to the atmosphere gradually combines with the carbon dioxid of the air and becomes calcium carbonate, thus releasing some soluble arsenic. For the results of this experiment, see Table XIII.

Arsenate of lead alone killed all larvæ in 8 days; combined with kerosene emulsion, 10 per cent, in 6 days (see Experiment XI); with lime-sulphur in 6 days, and with self-boiled lime-sulphur in 8 days. Commercial arsenate of calcium, powder, required 8 days to kill. Commercial arsenate of calcium, paste, required 27 days, but when combined with lime-sulphur solution, killed in 10 days.

TABLE XIII.—*Tests of the killing effect of various materials on the fall webworm.*

[Experiment started Aug. 14, 1914, Benton Harbor, Mich.; 10 larvæ in each lot.]

Lot No.	Name and dilution.	Dates of examination and number of larvæ dying in each lot.													Total number dead.	Number days required to kill.	Square inches foliage consumed.
		August—							September—								
		18	20	22	24	26	28	31	2	5	8	10	14	19			
1	Arsenate of lead paste, 4–50	3	6	1											10	8	(1)
2	Arsenate of calcium (commercial) paste, 4–50	0	0	0	2	1	0	1	2	1	2	1			10	27	29.84
3	Arsenate of calcium (commercial) powder, 2–50	1	6	3											10	8	1.00
4	Arsenate of calcium paste (homemade, formula 1), 4–50	1	0	1	4	1	1	1	0	0	1				10	25	6.25
5	Arsenate of calcium paste (homemade, formula 1), 4–50	0	0	4	2	1	0	0	0	0	0	1	1	0	9		15.50
6	Arsenate of calcium paste (homemade, formula 2), 4–50	0	0	1	7	1	1								10	14	6.00
7	Arsenate of calcium paste (homemade, formula 2), 2½–50	0	0	0	0	1	0	1	0	2	1	1	0	1	7		33.00
8	Arsenate of calcium paste (homemade, formula 3), 4–50	0	0	1	2	0	0	0	0	0	0	1	2	1	7		48.00
9	Arsenate of calcium paste (homemade, formula 3), 4–50	0	0	3	0	0	0	1	2	4					10	22	17.00
10	Arsenate of calcium paste (homemade, formula 4), 4–50	0	0	0	0	0	0	0	0	0	0	4	1	4	9		61.50
11	Arsenate of calcium paste (homemade, formula 4), 10–50	0	0	2	0	0	2	0	1	1	3	0	0	0	9		22.00
12	Arsenate of calcium paste (homemade, formula 5), 4–50	0	0	0	0	0	0	0	0	0	0	0	0	0	0		114.00
13	Arsenate of calcium paste (homemade, formula 5), 6–50	0	0	3	1	1	0	0	0	0	0	1	0	2	8		18.50
14	Arsenate of calcium paste (homemade, formula 6), 4–50 Slaking, not vigorous	0	2	1	2	0	0	2	2	1					10	22	13.00
15	Arsenate of calcium paste (homemade, formula 6), 4–50. Slaking, not vigorous	1	0	2	4	2	1								10	14	5.28
16	Arsenate of lead paste, 4–50+kerosene emulsion, 10 per cent	5	5												10	6	.80
17	Arsenate of calcium paste, commercial, 4–50+kerosene emulsion, 10 per cent	0	0	1	0	0	0	0	0	0	2	0	0	1	4		38.00
18	Arsenate of calcium paste (homemade, formula 3)+kerosene emulsion, 10 per cent	0	0	4	2	0	0	1	0	0	2	0	0	0	9		38.00
19	Kerosene emulsion, 10 per cent	0	0	0	0	0	0	0	0	0	0	0	0	0	0		72.00
20	Arsenate of lead paste, 4–50+lime-sulphur, 1½–50	6	4												10	6	.31
21	Arsenate of calcium (commercial) paste, 4–50+lime-sulphur, 1½–50	0	0	1	9										10	10	2.00
22	Arsenate of calcium (homemade, formula 3)+lime-sulphur, 1½–50	0	1	1	5	2	1								10	14	4.50
23	Sodium arsenate (crystals technically pure), 2 pounds+self-boiled lime-sulphur, 8–8–50	0	0	4	6										10	10	8.00
24	Arsenate of lead paste, 4–50+self-boiled lime-sulphur, 8–8–50	1	8	1											10	8	.56
25	Check (unsprayed)	0	0	0	0	0	0	0	0	0	0	0	1	0	1		72.00

[1] Not measured.

The homemade arsenate of calcium products, as noted previously, were low in arsenic oxid content, but as a whole proved relatively effective as poisoning agents. Formula (2), arsenic oxid 6.16 per cent, at the rate of 4 to 50, required 14 days, which was the same length of time required by formula (3), arsenic oxid 3.93 per cent, 4 to 50, combined with lime-sulphur solution. The arsenate of calcium prepared along with self-boiled lime-sulphur killed all larvæ in 10 days. The experiment was closed at the end of 36 days, only one larva of the unsprayed lot having died.

Experiment XIV.

Arsenate of calcium versus arsenate of lead, alone and combined with lime-sulphur solution, against larvæ of the fall webworm.

Homemade arsenate of calcium was again tested in comparison with commercial arsenate of calcium (paste and powder) and arsenate of lead, paste. These arsenicals were used alone and combined with lime-sulphur solution, 1½ to 50. The results of this experiment will be found in Table XIV.

Table XIV.—*Tests of the killing effect of various materials on the fall webworm.*

[Experiment started Aug. 27, 1914, Benton Harbor, Mich.; 10 larvæ in each lot.]

Lot No.	Name and dilution.	Dates of examination and number of larvæ dying in each lot.								Total number dead.	Number days required to kill.	Square inches foliage consumed.
		Aug. 31.	September—									
			2	5	8	10	14	16	19			
1	Arsenate of lead paste, 3–50	0	0	6	4	....	....	....	....	10	12	3.00
2	....do	0	0	9	1	....	....	....	....	10	12	3.00
3	Arsenate of lead paste, 3–50+lime-sulphur, 1½–50	0	1	6	2	1	....	....	....	10	14	2.25
4	....do	0	0	7	2	1	....	....	....	10	14	.25
5	Arsenate of lead paste, 5–50	0	0	8	2	....	....	....	....	10	12	2.50
6	....do	1	2	5	2	....	....	....	....	10	12	3.50
7	Arsenate of lead paste, 5–50+lime-sulphur, 1½–50	0	1	5	4	....	....	....	....	10	12	.50
8	....do	0	0	3	4	3	....	....	....	10	14	1.50
9	Arsenate of calcium, commercial paste, 5–50	0	0	0	0	0	3	0	1	4	.....	63.00
10	....do	0	0	0	0	4	1	1	0	6	.....	38.00
11	Arsenate of calcium, commercial paste, 5–50+lime-sulphur, 1½–50	0	0	3	4	3	....	....	....	10	14	13.50
12	....do	0	1	1	6	2	....	....	....	10	14	3.75
13	Arsenate of calcium, commercial powder, 2½–50	0	0	0	7	3	....	....	....	10	14	10.50
14	....do	0	1	2	0	3	4	....	....	10	18	20.05
15	Arsenate of calcium, commercial powder, 2½–50+lime-sulphur, 1½–50	1	0	3	2	4	....	....	....	10	14	4.00
16	....do	0	1	4	5	....	....	....	....	10	12	1.75
17	Arsenate of calcium (homemade paste, formula 1), 5–50	0	0	0	0	2	1	0	0	3	.....	42.00
18	....do	0	0	0	0	3	0	0	2	5	.....	27.50
19	Arsenate of calcium (homemade paste, formula 1), 5–50+lime-sulphur, 1½–50	0	0	4	4	0	2	....	....	10	18	9.25
20	....do	0	0	2	4	3	0	1	....	10	20	10.00
21	Arsenate of calcium (homemade paste, formula 3), 5–50	0	0	0	0	1	1	1	0	3	.....	63.00
22	....do	0	0	0	0	0	0	0	0	0	.....	72.25
23	Arsenate of calcium (homemade paste, formula 3), 5–50+lime-sulphur, 1½–50	0	3	0	1	0	6	....	....	10	18	19.50
24	....do	0	0	3	3	4	....	....	....	10	14	17.00
25	Lime-sulphur, 1½–50	0	3	2	1	3	0	1	....	10	20	8.00
26	....do	0	1	3	2	4	....	....	....	10	14	1.25
27	Check (unsprayed)	1	0	0	0	0	0	0	0	1	.....	81.00
28	....do	1	1	0	1	2	0	0	0	5	.....	69.25

As will be noted in Table XIV, arsenate of lead as usual killed the larvæ more quickly than any of the other arsenicals. Arsenate of lead paste at the rate of 3 to 50 or 5 to 50 required 12 days to kill all of the larvæ; when combined with lime-sulphur it required slightly longer with a decreased amount of feeding.

As shown in the preceding experiments of 1914, commercial arsenate of calcium when combined with lime-sulphur is a relatively effective poison. Likewise, in this experiment, both lots of the paste form in combination with lime-sulphur killed in 14 days; the powdered form mixed with lime-sulphur in 14 and 12 days.

The homemade arsenate of calcium compounds, when employed with lime-sulphur, were also relatively effective, especially when their low arsenical content is taken into consideration. Homemade arsenate of calcium, formula 1 ($As_2O_5 = 4.19$ per cent), plus lime-sulphur, was effective in killing all the larvæ of both lots in 18 and 20 days. Homemade arsenate of calcium, formula 3 ($As_2O_5 = 3.93$ per cent), required 18 and 14 days.

Experiment XV.

Comparison of the killing effect of various contact poisons on Aphis pomi.

A series of laboratory tests was made with various contact insecticides, alone and combined with other materials, against the green apple aphis (*Aphis pomi* De G.). Apple twigs well infested with this species were thoroughly sprayed and then placed in separate glasses containing water. The results were taken one day after date of application. Four tests were made, namely, (1) August 20, p. m.; (2) August 21, a. m.; (3) August 21, p. m.; and (4) September 17. For test (1) all the materials were freshly combined except No. 17, which had been mixed several days previous to its application. The spray materials used in tests (2) and (3) were the same as those employed in test (1), except that they had stood mixed about 18 and 24 hours, respectively, before usage. The chief object of tests (2) and (3) was to ascertain whether or not the mixing of these materials some time in advance of their use would affect their insecticidal value. In test (4) a bucket pump was used for applying the spray, a hand atomizer being used in the other three tests. The results of this experiment appear in Table XV.

TABLE XV.—*Aphis pomi, contact insecticide experiments.*

[Benton Harbor, Mich., 1914.]

Lot No.	Name and dilution.	Per cent of aphides killed.			
		Test 1, Aug. 20, p. m.	Test 2, Aug. 21, a. m.	Test 3, Aug. 21, p. m.	Test 4, Sept. 17.
1	Nicotine sulphate (Com. No. 1), 40 per cent, 1–800	100	100	100	.....
2	Nicotine sulphate (Com. No. 1), 40 per cent, 1–800+laundry soap, 3–50	100	100	100	100
3	Nicotine sulphate (Com. No. 1), 40 per cent, 1–1,200+laundry soap, 3–50	.....	.....	.....	100
4	Nicotine sulphate (Com. No. 1), 40 per cent, 1–1,600+laundry soap, 3–50	.....	.....	.....	100
5	Nicotine sulphate (Com. No. 1), 40 per cent, 1–2,000+laundry soap, 3–50	.....	.....	.....	100
6	Nicotine sulphate (Com. No. 1), 40 per cent, 1–800+arsenate of lead paste, 2–50	100	100	100	.....
7	Nicotine sulphate (Com. No. 1), 40 per cent, 1–800+arsenate of lead paste, 2–50+laundry soap, 3–50	100	100	100	.....
8	Nicotine sulphate (Com. No. 2), 40 per cent, 1–800	100	100	100	.....
9	Nicotine sulphate (Com. No. 2), 40 per cent, 1–800+arsenate of lead paste, 2–50	100	100	100	.....
10	Nicotine sulphate (Com. No. 2), 40 per cent, 1–800+laundry soap, 3–50	100	100	100	100
11	Nicotine sulphate (Com. No. 2), 40 per cent, 1–800+laundry soap, 3–50+arsenate of lead paste, 2–50	100	100	100	.....
12	Kerosene emulsion (66 per cent stock), 1 per cent	.....	.....	.....	0
13	Kerosene emulsion (66 per cent stock), 3 per cent	.....	.....	.....	35
14	Kerosene emulsion (66 per cent stock), 5 per cent	.....	.....	.....	100
15	Kerosene emulsion (66 per cent stock), 10 per cent	100	100	100	100
16	Kerosene emulsion (66 per cent stock), 10 per cent+arsenate of lead paste, 2–50	100	100	100	.....
[1]17	Kerosene emulsion (66 per cent stock), 10 per cent+arsenate of lead paste, 2–50	[2] 95	[2] 98	[2] 98	.....
18	Kerosene emulsion (66 per cent stock), 10 per cent+arsenate of calcium, commercial paste, 2–50	100	100	100	.....
19	Kerosene emulsion (66 per cent stock), 10 per cent+arsenate of calcium, commercial paste, 2–50	100	100	100	.....
20	Anthracene emulsion (66 per cent stock), 5 per cent	[3] 100	[3] 100	[3] 100	.....
21	Anthracene emulsion (50 per cent stock), 3 per cent	.....	.....	.....	100
22	Anthracene emulsion (50 per cent stock), 1 per cent	.....	.....	.....	75
23	Laundry soap, 3–50	[4] 75	[4] 75	[4] 75	15
24	Laundry soap, 5–50	.....	.....	.....	50
25	Nicotine sulphate (Com. No. 1), 40 per cent, 1–800+arsenate of lead paste, 2–50+lime-sulphur, 1½–50	100	100	100	.....
26	Nicotine sulphate (Com. No. 2), 40 per cent, 1–800+arsenate of lead paste, 2–50+lime-sulphur, 1½–50	100	100	100	.....
27	Arsenate of lead paste, 2–50	0	[5] 10	0	.....
28	Naphtha soap, 3–50	.....	.....	.....	0
29	Naphtha soap, 5–50	.....	.....	.....	0
30	Kerosene emulsion (50 per cent stock—made with naphtha soap, cold water), 10 per cent	.....	.....	.....	85
31	Kerosene emulsion (50 per cent stock—made with naphtha soap, cold water), 5 per cent	.....	.....	.....	50
32	Kerosene emulsion (naphtha soap, cold water), 10 per cent	.....	.....	.....	100
33	Anthracene emulsion (50 per cent stock—made with naphtha soap, cold water), 3 per cent	.....	.....	.....	100
34	Anthracene emulsion (50 per cent stock—made with naphtha soap, cold water), 1 per cent	.....	.....	.....	25
35	Fish-oil soap, 3–50	.....	.....	.....	10
36	Fish-oil soap, 5–50	.....	.....	.....	90
37	Nicotine sulphate (Com. No. 2), 40 per cent, 1–1,200+laundry soap, 3–50	.....	.....	.....	100
38	Nicotine sulphate (Com. No. 2), 40 per cent, 1–1,600+laundry soap, 3–50	.....	.....	.....	100
39	Nicotine sulphate (Com. No. 2), 40 per cent, 1–2,000+laundry soap, 3–50	.....	.....	.....	100
40	Check (unsprayed)	0	0	0	0

[1] Stood combined several days before usage.
[2] A few adults not killed.
[3] Foliage severely burned.
[4] Adult aphides not killed.
[5] No adult aphides killed.

As will be noted in Table XV, the majority of the materials proved effective aphidicides. Thus it will be seen that several combinations may be used with good effect when it is aimed to control both chew-

ing and sucking insects at the same time. It would appear that it is not well to allow kerosene emulsion and arsenate of lead to stand combined too long previous to its application, if the best results are to be obtained. However, a standing for a day or so would make no material difference, since there is but slight breaking down of the soap. In general, insecticides should not be combined until they are to be used. Anthracene emulsion, 5 per cent, burned the foliage badly. Laundry soap, 3 to 50, was effective against the young aphides only. Arsenate of lead alone, as was to be expected, had little or no effect upon the aphides. The combination of arsenate of calcium with kerosene emulsion is not a desirable one, since an insoluble calcium soap is formed, thereby releasing some free kerosene.

According to the results of the above experiment a 10 per cent kerosene emulsion should prove effective against the green apple aphis. In one instance, however, not all of the aphides were killed. The nicotine solutions, with a dilution up to 1 to 2,000 combined with soap, were likewise effective aphidicides. Anthracene emulsion, 3 per cent, gave satisfactory control, and at this strength caused no foliage injury. The kerosene emulsions under 10 per cent were not satisfactory, neither were the soaps at the strengths tested, except that fish-oil soap, 5 to 50, killed 90 per cent of the aphides.

FIELD EXPERIMENTS.

POISON TESTS IN EXPERIMENTAL APPLE ORCHARD.

The Ben Davis orchard which had been used for experimental purposes during the seasons of 1912 and 1913 was again secured for continued investigations. The orchard was in very fair condition and responded very creditably in fruit production, the crop in 1914 being larger than any produced in the past. The experiments included tests of insecticides combined with fungicides, since, in commercial orcharding, a combination spray is usually made. Most of the plats received five spray applications, namely: (1) Dormant application, April 16 and 17; (2) cluster-bud stage, May 5 and 6; (3) when petals dropped, May 23, 25, and 26; (4) three to four weeks later, June 15, 16, and 17; (5) nine weeks after petals dropped, July 27 and 28. The orchard was sprayed with a power outfit having a pressure averaging about 225 pounds.

The results of the investigations as reported in the succeeding pages were obtained from an examination of the fruit. Certain trees in each plat are designated as count trees. The dropped fruit from the count trees was picked up and examined weekly throughout the season, and at harvesting time the picked fruit was likewise examined. The more important results of the experiments for the control of the codling moth are herewith reported.

Experiment XVI.

Field tests of arsenate of calcium versus arsenate of lead against the codling moth, 1914.

One of the most promising of the insecticides tested during the season of 1914 was an arsenate of calcium paste. A commercial article was employed at the rate of 2 pounds to each 50 gallons of lime-sulphur solution. The plat sprayed with this material consisted of 12 trees, the fruit from five of which was examined throughout the season. The plat sprayed with arsenate of lead paste, 2 pounds combined with 50 gallons lime-sulphur solution, included 12 trees, the fruit from six of which was examined. Plats III, IV, and V, located in different parts of the orchard, were left unsprayed as a check. These plats had a total of eight trees, all of which were examined. Three applications were given Plats I and II, for the control of the codling moth: (1) When petals dropped; (2) three to four weeks later; (3) nine weeks after petals dropped, for the control of the second brood.

The arsenate of calcium paste was analyzed by the Bureau of Chemistry, United States Department of Agriculture, as follows:

Analysis of arsenate of calcium (paste).

	Per cent.
Moisture	55.80
Total arsenic oxid, As_2O_5	18.82
Total calcium oxid, CaO	17.93
Total lead oxid, PbO	3.72
Soluble impurities, exclusive of PbO and As_2O_5	1.84
Water of constitution and undetermined (small amount of CO_2)	1.89
Total	100.00
Soluble arsenic	Trace.

This sample contains lead equivalent to approximately 5.5 per cent lead arsenate. The results of this experiment are shown in Table XVI.

Table XVI.—*Sound and wormy apples from sprayed and unsprayed plats.*

[Poison test. A comparison of arsenate of calcium with arsenate of lead. Benton Harbor, Mich., 1914.]

Plat number.	Treatment.	Tree No.	Condition of fruit.			
			Wormy.	Sound.	Total.	Per cent sound.
I	Arsenate of calcium (commercial paste), 2 pounds to 50 gallons lime-sulphur solution.	1	123	8,087	8,210	98.50
		2	78	5,424	5,502	98.58
		3	47	4,988	5,035	99.06
		4	44	6,132	6,176	99.43
		5	63	4,283	4,346	98.56
	Plat total		355	28,914	29,269	98.79

TABLE XVI.—*Sound and wormy apples from sprayed and unsprayed plats*—Contd.

Plat number.	Treatment.	Tree No.	Condition of fruit.			
			Wormy.	Sound.	Total.	Per cent sound.
II.....	Arsenate of lead (paste), 2 pounds to 50 gallons lime-sulphur solution.	1	29	3,777	3,806	99.24
		2	12	2,399	2,411	99.59
		3	28	5,146	5,174	99.46
		4	13	3,833	3,846	99.66
		5	26	3,972	3,998	99.35
		6	26	4,757	4,783	99.46
	Plat total.....	.....	134	23,884	24,018	99.44
III–V..	Checks (unsprayed).....	1	1,548	3,907	5,455	71.62
		2	3,208	5,556	8,764	63.40
		3	2,342	5,682	8,024	70.81
		4	2,432	4,116	6,548	62.86
		5	2,635	3,722	6,357	58.55
		6	2,385	1,566	3,951	39.64
		7	2,902	2,197	5,099	43.09
		8	2,312	1,356	3,668	36.94
	Plat total.....	.....	19,764	28,102	47,866	58.71

As will be noted in Table XVI, out of 29,269 apples from the plat sprayed with arsenate of calcium 98.79 per cent were free from codling moth. The fruit examined on Plat II, 24,018 apples, sprayed with arsenate of lead, was 99.44 per cent free from the codling moth. The unsprayed trees yielded 47,866 apples, of which but 58.71 per cent were free from worms.

It will thus be seen that the arsenate of calcium compared very favorably with the arsenate of lead, and since it can be produced more cheaply than the lead arsenate it would appear to have distinct value. The foliage in Plat I was as healthy appearing as in Plat II throughout the season, and, further, the fungicidal value of lime-sulphur was practically the same, whether arsenate of calcium or arsenate of lead was used. While arsenate of calcium has not been sufficiently tested to recommend it for general use, yet it would seem that this arsenical will probably serve as a satisfactory and cheap substitute for arsenate of lead. Arsenate of calcium may be manufactured either in the paste or powdered form or made at home in the paste form.

HOMEMADE ARSENATE OF CALCIUM.

Arsenate of calcium may be prepared at home from various chemicals, the more important being arsenic acid and lime, sodium arsenate and calcium chlorid, sodium arsenate and calcium acetate, etc. Potassium dihydrogen arsenate may be substituted for the sodium arsenate, but is more expensive and would have no distinct advantages over the latter.

The logical way to make arsenate of calcium is by combining arsenic acid with lime, but at the present writing arsenic acid can

not be obtained on the market to advantage. In view of this fact arsenate of calcium may be prepared at home by combining fused (dry powdered) sodium arsenate with lime. The by-product is largely sodium hydroxid, most of which may be decanted. It is possible that decantation will not be necessary when the arsenate of calcium is to be applied to foliage that is not too tender. The formula for making is herewith given:

Stone lime (90 per cent CaO)	pounds..	55
Sodium arsenate, fused (dry powdered) 65 per cent As_2O_5	do....	100
Water	gallons..	26

Place the stone lime in a wooden container and add a small amount of water, just enough to start slaking. When slaking is well under way pour in the sodium arsenate, which should first have been dissolved in hot water. Keep stirring until the lime has thoroughly slaked. Sufficient water should be added from time to time to prevent burning.

The resulting arsenate of calcium should contain about 18 per cent of arsenic oxid. In making this compound it will of course be necessary to know approximately the calcium oxid and arsenic oxid content of the materials employed and to vary the formula accordingly.

Arsenate of calcium was prepared at the laboratory in the proportions as given below:

Stone lime[1] (80 per cent CaO)	pounds..	6
Sodium arsenate,[2] fused (dry powdered) 62 per cent As_2O_5	do....	10
Water	gallons..	2

The above was analyzed by the Bureau of Chemistry, United States Department of Agriculture, as follows:

	Per cent.
Moisture	46.90
Total arsenic oxid, As_2O_5	20.37
Total arsenious oxid, As_2O_3	.21
Calcium oxid, CaO	18.95
Carbon dioxid, CO_2	.18
Undetermined, mainly sodium hydrate	13.39
Total	100.00
Soluble arsenic oxid, As_2O_5	.04

Experiment XVII.

Field tests of powdered arsenate of lead versus paste arsenate of lead against the codling moth, 1914.

Since the advent of the powdered form of arsenate of lead the question has naturally arisen as to whether this newer form of the arsenical is as effective as the older or paste form. The powdered arsenate of lead has been on the market for several years and is now being recommended by several manufacturers, who claim for it

[1] This lime was not well burned, since it contained considerable calcium carbonate.

[2] Sodium arsenate, fused (dry powdered) $Na_2H\ AsO_4$. As_2O_5=61.86 per cent; As_2O_3=1.42 per cent.

certain advantages. The principal points given in favor of the powder over the paste are that it can be more conveniently mixed, that the proper amount to be used for each spray tank may be weighed out with a greater degree of accuracy, and that it can be stored more readily without deterioration. There is also a distinct saving in freight. For the advantages enumerated the fruit grower is asked to pay a trifle more in price, since it costs the manufacturer somewhat more to produce the powdered form.

With this in view, experiments were conducted to test the efficiency of the powdered form in comparison with the paste. Since the powdered arsenical has approximately twice the strength of the paste, one-fourth pound of the powder was directly compared with one-half pound of the paste, one-half pound of the powder was compared with 1 pound of the paste, and 1 pound of the powder was compared with 2 pounds of the paste. All of these were combined with 50 gallons of lime-sulphur solution, with the exception of Plat IV, where a commercial precipitated sulphur was employed.

Three spray applications against the codling moth were made: (1) when petals dropped; (2) 3 to 4 weeks later; (3) 9 weeks after petals dropped for second-brood larvæ.

The dropped fruit from certain count trees in each plat was picked up weekly and examined. The fruit gathered at harvest time was likewise examined and the results recorded.

Plat I consisted of 9 trees, the fruit from 5 of which was examined; Plat II, 9 trees, 5 examined; Plat III, 4 trees, 3 examined; Plat IV, 5 trees, 3 examined; Plat V, 9 trees, 5 examined; Plat VI, 7 trees, 5 examined; Plat VII, 12 trees, 6 examined; Plats VIII, IX, and X, total 8 trees, 8 examined. For the results of this experiment see Table XVII.

TABLE XVII.—*Sound and wormy apples from sprayed and unsprayed plats.*

[Benton Harbor, Mich., 1914. Poison test. Comparison of arsenate of lead in powdered and paste form.]

Plat No.	Treatment.	Tree No.	Condition of fruit.			
			Wormy.	Sound.	Total.	Per cent sound.
I	Arsenate of lead (powder), ¼ pound to 50 gallons lime-sulphur solution	1	28	667	695	95.97
		2	16	1,036	1,052	98.48
		3	155	3,052	3,207	95.17
		4	117	1,650	1,767	93.38
		5	61	806	867	92.96
	Plat total		377	7,211	7,588	95.03
II	Arsenate of lead (paste), ½ pound to 50 gallons lime-sulphur solution	1	387	6,979	7,366	94.75
		2	221	5,282	5,503	95.98
		3	222	5,064	5,286	95.80
		4	355	5,098	5,453	93.49
		5	128	3,771	3,899	96.72
	Plat total		1,313	26,194	27,507	95.22

TABLE XVII.—*Sound and wormy apples from sprayed and unsprayed plats*—Contd.

Plat No.	Treatment.	Tree No.	Condition of fruit.			
			Wormy.	Sound.	Total.	Per cent sound.
III	Arsenate of lead (powder), ½ pound to 50 gallons lime-sulphur solution	1	97	7,250	7,347	98.68
		2	123	5,615	5,738	97.85
		3	68	6,315	6,383	98.93
	Plat total	.....	288	19,180	19,468	98.52
IV	Arsenate of lead (powder), ½ pound combined with commercial precipitated sulphur, 7 pounds, to 50 gallons water	1	44	5,618	5,662	99.22
		2	93	8,958	9,051	98.97
		3	82	7,791	7,873	98.96
	Plat total	.....	219	22,367	22,586	99.03
V	Arsenate of lead (paste), 1 pound to 50 gallons lime-sulphur solution	1	74	6,160	6,234	98.81
		2	39	4,163	4,202	99.07
		3	65	4,836	4,901	98.67
		4	64	6,394	6,458	99.01
		5	76	5,787	5,863	98.69
	Plat total	.....	318	27,340	27,658	98.13
VI	Arsenate of lead (powder), 1 pound to 50 gallons lime-sulphur solution	1	123	5,043	5,166	97.62
		2	41	6,718	6,759	99.39
		3	79	5,418	5,497	98.56
		4	51	7,224	7,275	99.30
		5	121	7,749	7,870	98.46
	Plat total	.....	415	32,152	32,567	98.73
VII	Arsenate of lead (paste), 2 pounds to 50 gallons lime-sulphur solution	1	29	3,777	3,806	99.24
		2	12	2,399	2,411	99.59
		3	28	5,146	5,174	99.46
		4	13	3,833	3,846	99.66
		5	26	3,972	3,998	99.35
		6	26	4,757	4,783	99.46
	Plat total	.....	134	23,884	24,018	99.44
VIII–X	Checks (unsprayed)	1	1,548	3,907	5,455	71.62
		2	3,208	5,556	8,764	63.40
		3	2,342	5,682	8,024	70.81
		4	2,432	4,116	6,548	62.86
		5	2,635	3,722	6,357	58.55
		6	2,385	1,566	3,951	39.64
		7	2,902	2,197	5,099	43.09
		8	2,312	1,356	3,668	36.94
	Plat total	.....	19,764	28,102	47,866	58.71

As will be noted in Table XVII, there is practically no difference from an insecticidal point of view in the effectiveness of the powdered and the paste arsenate of lead. The fruit grower would be justified in using the powdered form if the present difference in cost is considered reasonable for the advantages secured.

One-fourth pound of the powdered arsenate of lead gave 95.03 per cent of fruit free from codling moth against 95.22 per cent where one-half pound of the paste was used. The two plats sprayed with one-half pound of the powder gave 98.52 and 99.03 per cent of sound fruit, respectively, as compared with 98.13 per cent for 1 pound of the paste. One pound of the powder averaged 98.73 per cent sound

against 99.44 per cent for 2 pounds of the paste. The unsprayed trees yielded 47,866 apples, of which number 58.71 per cent were free from codling-moth infestation.

Experiment XVIII.

Field tests of various arsenicals combined with fungicides against the codling moth, 1914.

Arsenate of lead was tested against the codling moth in combination with the following commercial fungicides, namely, lime-sulphur, commercial; precipitated sulphur, commercial; sodium sulphid, commercial; and commercial barium tetrasulphid compound. The following combinations were also tested:

Arsenite of zinc (paste) was used at the rate of 1½ pounds combined with Bordeaux mixture 4–4–50. This arsenical was added to the lime while being slaked for the Bordeaux mixture.

Arsenite of zinc (paste), 1½ pounds, was added to 2 pounds stone lime while the lime was slaking. This was mixed with 50 gallons lime-sulphur solution.

Arsenate of zinc (homemade), prepared from sodium arsenate crystals and zinc sulphate, was used at the rate of eight-tenths pound sodium arsenate to 50 gallons lime-sulphur solution. Three spray applications were made with the above combinations. The results of this experiment will be found in Table XVIII.

Table XVIII.—*Sound and wormy apples from sprayed and unsprayed plats.*

[Poison test. Miscellaneous. Benton Harbor, Mich., 1914.]

Plat No.	Treatment.	Tree No.	Condition of fruit.			
			Wormy.	Sound.	Total.	Per cent sound.
I	Arsenate of lead (paste), 2 pounds to 50 gallons lime-sulphur solution.	1	29	3,777	3,806	99.24
		2	12	2,399	2,411	99.59
		3	28	5,146	5,174	99.46
		4	13	3,833	3,846	99.66
		5	26	3,972	3,998	99.35
		6	26	4,757	4,783	99.46
	Plat total		134	23,884	24,018	99.44
II	Arsenate of lead (powder), ½ pound + commercial precipitated sulphur, 7 pounds, to 50.	1	44	5,618	5,662	99.22
		2	93	8,958	9,051	98.97
		3	82	7,791	7,873	98.96
	Plat total		219	22,367	22,586	99.03
III	Arsenate of lead (paste), 2 pounds + commercial sodium sulphid, 2 pounds, to 50.	1	72	7,898	7,970	99.08
		2	30	7,784	7,814	99.62
		3	34	8,739	8,773	99.61
	Plat total		136	24,421	24,557	99.45
IV	Arsenate of lead (paste), 2 pounds + stone lime, 2 pounds + commercial sodium sulphid, 2 pounds, to 50.	1	35	8,295	8,330	99.58
		2	22	6,269	6,291	99.65
		3	39	9,639	9,678	99.60
	Plat total		96	24,203	24,299	99.65

TABLE XVIII.—*Sound and wormy apples from sprayed and unsprayed plats*—Contd.

Plat No.	Treatment.	Tree No.	Condition of fruit.			
			Wormy.	Sound.	Total.	Per cent sound.
V	Arsenate of lead (paste), 2 pounds + commercial barium tetrasulphid 5–50.	1	806	9,224	10,030	90.97
		2	450	7,864	8,314	94.59
		3	216	6,988	7,204	97.00
		4	258	7,107	7,365	97.85
		5	328	10,340	10,668	96.91
	Plat total		**2,058**	**41,523**	**43,581**	**95.28**
VI	Arsenite of zinc (paste), 1½ pounds + Bordeaux mixture 4–4–50.	1	42	3,982	4,024	98.96
		2	29	5,121	5,150	99.44
		3	27	3,231	3,258	99.17
	Plat total		**98**	**12,334**	**12,432**	**99.21**
VII	Arsenite of zinc (paste), 1½ pounds + stone lime, 2 pounds, to 50 gallons lime-sulphur solution.	1	347	4,092	4,439	92.18
		2	244	5,478	5,722	95.74
		3	274	5,885	6,159	90.68
	Plat total		**865**	**15,455**	**16,320**	**94.70**
VIII	Arsenate of zinc (homemade), sodium arsenate crystals, ⅞ pound, to 50 gallons lime-sulphur solution	1	221	3,654	3,875	94.30
		2	167	3,544	3,711	95.50
		3	309	5,306	5,615	94.50
	Plat total		**697**	**12,504**	**13,201**	**94.72**
IX–XI	Checks (unsprayed)	1	1,548	3,907	5,455	71.62
		2	3,208	5,556	8,764	63.40
		3	2,342	5,682	8,024	70.81
		4	2,432	4,116	6,548	62.86
		5	2,635	3,722	6,357	58.55
		6	2,385	1,566	3,951	39.64
		7	2,902	2,197	5,099	43.09
		8	2,312	1,356	3,668	36.94
	Plat total		**19,764**	**28,102**	**47,866**	**58.71**

Arsenate of lead gave satisfactory control of the codling moth when combined with lime-sulphur, commercial precipitated sulphur, and commercial barium tetrasulphid. In combination with commercial sodium sulphid, lead arsenate held the codling moth in check, but caused considerable foliage injury and defoliation due to the formation of soluble sodium arsenate. The addition of lime lessened the foliage injury somewhat.

Arsenate of zinc, when added to lime being slaked for Bordeaux mixture, was effective and caused no foliage injury. Arsenite of zinc added to slaking lime and then mixed with lime-sulphur solution, and likewise arsenate of zinc (homemade) combined with lime-sulphur solution, were slightly less effective than the other arsenical combinations.

EXPERIMENT XIX.

COMBINATION SPRAYS—COMPATIBLES AND INCOMPATIBLES.

Combination sprays for the control of apple chewing and sucking insects and fungous diseases were tested in the experimental orchard. Arsenate of lead with nicotine solutions and lime-sulphur solution is a compatible mixture and will give satisfactory results if the application is timely.

Arsenate of lead, kerosene emulsion, and lime-sulphur in combination is an incompatible mixture, usually causing severe injury to the foliage. The calcium of the lime-sulphur breaks down the soap of the kerosene emulsion, forming an insoluble calcium soap. The result is that free kerosene is released in sufficient quantity to cause foliage injury.

A combination of lime-sulphur and kerosene emulsion, 10 per cent, was tested on apple in the cluster-bud stage to determine the extent of damage likely to occur. The plat which later received one-fourth pound to 50 of powdered arsenate of lead was used for the test. Both the foliage and unopened blossoms were so seriously injured as to reduce materially the size of the crop.

By reference to Table XVII the effect upon the crop yield will be noted. All plats in this table having five count trees were sprayed with lime-sulphur alone during the cluster-bud stage except Plat I. Plat I, which was sprayed with the combination of lime-sulphur and kerosene emulsion, yielded 7,588 apples (39 bushels); Plat II, 27,507 apples (109.5 bushels); Plat V, 27,658 apples (118 bushels); Plat VI, 32,567 apples (128.5 bushels). The number of bushels represents the amount of fruit picked from the trees at harvest time. An estimate of the loss of crop per tree due to the application of lime-sulphur and kerosene emulsion is approximately 16 bushels, or, in other words, the normal crop yield was reduced to about 33 per cent of that from the lime-sulphur plats alone.

Lime-sulphur and soap in combination is likewise impracticable, since a calcium soap is thrown out, thus weakening the value of each material.

Diplumbic arsenate of lead, especially the powdered form which is chiefly diplumbic, is likely to cause foliage injury when combined with an alkalin solution, such as sodium sulphid. But when combined with lime-sulphur some calcium arsenate is formed. This is comparatively insoluble, and hence the possibility of burning is reduced.

Experiment XX.

Comparison of soda, potash, and sulphur sprays against the San Jose scale.

The pear orchard owned by Mr. John Hamilton, of Benton Harbor, Mich., was used for the San Jose scale insecticide investigations. This orchard consisted of 209 trees about 15 years of age. Four varieties, planted in separate rows, were represented as follows: Three rows of Bartlett, one row Clairgeau, three rows Beurré d'Anjou, and one row Seckle. This orchard had been more or less neglected for several years and was accordingly quite uniformly infested with the scale. The orchard was divided into nine plats so as to include all varieties in each plat, so far as possible. Trees were left un-

sprayed at each end of the orchard and also in central sections as a basis for comparison with the sprayed. The spray materials were applied while the trees were dormant, April 10, 11, and 13, using a small power outfit.

To determine the efficacy of the scale insecticides two methods were employed; first, the examination of the scale-infested twigs for dead and live scales by means of the binocular microscope. This method proved to be anything but satisfactory. The second and better method of determining results was the examination of the fruit for scale which crawled thereon. All of the dropped fruit from the count trees was picked up and examined weekly throughout the season. The picked fruit at harvest time was also examined. In Table XIX will be found the results according to variety. Table XX is a commercial summary of Table XIX.

As will be noted in Table XX (commercial summary), the percentage of fruit (all varieties) free from scale and that with a light infestation has been combined for a comparison with the percentage of fruit with an infestation medium and heavy. The scale upon the fruit classified as lightly infested was usually found more or less concealed in the calyx cavity and, therefore, did not mar the appearance of the fruit for market. Furthermore, a large percentage of the fruit lightly infested had but two or three scales per fruit.

The fruit with a medium and heavy scale infestation was unmarketable. Frequently the fruit in the heavy scale infestation class was blood red in appearance and would average 500 to 1,000 scales per fruit. This condition was chiefly found on the unsprayed trees, whose foliage was likewise heavily infested with the scale insects.

TABLE XIX.—*San Jose scale insecticide investigations, Benton Harbor, Mich., 1914.*

Plat.	Name and dilution.	Number of count trees.				Number of fruits.				Per cent of fruit. Free from scale.			
		Bartlett.	Clairgeau.	Anjou.	Seckel.	Bartlett.	Clairgeau.	Anjou.	Seckel.	Bartlett.	Clairgeau.	Anjou.	Seckel.
I	Lime-sulphur, 1-7	8	3	5	3	1,841	453	242	389	75.667	53.201	51.241	68.637
II	(1) Commercial sodium sulphid, 12.5 pounds-50	5	2	2	1	1,717	306	94	10	59.059	41.505	20.215	90.000
III	Caustic potash, 11 pounds+sulphur, 12.5 pounds-50	2	0	3	2	1,008	0	191	1,522	25.101	.....	30.892	39.490
IV	(2) Commercial sodium sulphid, 12.5 pounds-50	0	2	3	0	0	435	238	0	.....	38.622	32.774	.....
V	Caustic soda, 11 pounds+sulphur, 12.5 pounds-50	4	1	2	0	1,865	139	140	0	78.709	34.559	41.430	.....
VI	Lime-sulphur, 1-7+nitrate of soda, 50 pounds-50	6	0	2	2	946	0	113	15	76.289	.....	50.445	80.000
VII	Caustic soda, 15 pounds+sulphur, 17.1 pounds-50	5	1	2	1	1,531	143	208	521	89.877	51.750	70.194	54.892
VIII	Caustic potash, 15 pounds+sulphur, 17.1 pounds-50	4	1	3	0	1,116	179	263	0	89.247	78.771	51.716	.....
IX	Check—unsprayed	33	2	11	3	8,100	299	1,825	4,474	52.595	25.420	8.056	6.841

TABLE XIX.—*San Jose scale insecticide investigations, Benton Harbor, Mich., 1914*—Continued.

Plat.	Name and dilution.	Per cent of fruit.											
		Light infestation, 1–10 scales.				Medium infestation, 11–20 scales.				Heavy infestation, 21–over scales.			
		Bartlett.	Clairgeau.	Anjou.	Seckel.	Bartlett.	Clairgeau.	Anjou.	Seckel.	Bartlett.	Clairgeau.	Anjou.	Seckel.
I	Lime-sulphur, 1–7	23.954	33.554	38.016	26.737	0.271	13.245	8.677	3.598	0.108	0	2.066	1.028
II	(1) Commercial sodium sulphid, 12.5 pounds–50	36.167	50.000	67.021	10.000	3.377	6.535	6.382	0	1.397	1.960	6.382	0
III	Caustic potash, 11 pounds+sulphur, 12.5 pounds–50	61.111	.....	49.738	42.312	11.011	.....	7.339	6.570	2.777	.....	12.041	11.628
IV	(2) Commercial sodium sulphid, 12.5 pounds–50	.....	46.666	39.916	.....	.....	12.873	14.705	.....	.....	1.839	12.605	.....
V	Caustic soda, 11 pounds+sulphur, 12.5 pounds–50	20.005	36.690	48.571	.....	1.018	21.561	7.857	.....	.268	7.19	2.142	.....
VI	Lime-sulphur, 1–7+nitrate of soda, 50 pounds–50	22.305	.....	40.707	20.000	1.313	.....	5.309	0	.093	.....	3.539	0
VII	Caustic soda, 15 pounds+sulphur, 17.1 pounds–50	9.797	46.153	28.365	39.731	.261	1.398	.961	4.418	.065	.699	.480	.959
VIII	Caustic potash, 15 pounds+sulphur, 17.1 pounds–50	10.663	21.229	43.722	.....	.090	0	2.661	.....	0	0	1.901	.....
IX	Check—unsprayed	25.654	48.829	18.356	33.281	6.358	14.046	9.205	18.506	15.393	11.705	64.383	41.372

TABLE XX.—*San Jose scale insecticide investigations (commercial table), Benton Harbor, Mich., 1914.*

Plat.	Name and dilution.	Number of count trees.	Total number of fruits.	Per cent of fruit.	
				Free from scale to light infestation, marketable.	Medium to heavy infestation, unmarketable.
I	Lime-sulphur, 1–7	19	2,925	98.052	1.948
II	(1) Commercial sodium sulphid, 12.5 pounds–50	11	2,127	94.359	5.641
III	Caustic potash, 11 pounds+sulphur, 12.5 pounds–50	7	2,721	83.352	16.648
IV	(2) Commercial sodium sulphid, 12.5 pounds–50	5	673	80.833	19.167
V	Caustic soda, 11 pounds+sulphur, 12.5 pounds–50	7	2,144	97.942	2.058
VI	Lime-sulphur, 1–7+nitrate of soda, 50 pounds–50	11	1,074	98.511	1.489
VII	Caustic soda, 15 pounds+sulphur, 17.1 pounds–50	8	2,403	98.378	1.622
VIII	Caustic potash, 15 pounds+sulphur, 17.1 pounds–50	8	1,558	99.167	.833
IX–XI	Checks—unsprayed	49	14,693	60.793	39.207

Although the spray materials were subjected to a severe test, all, with the exception of the materials employed in Plats III and IV, gave satisfactory results. Lime-sulphur was used alone and also in combination with nitrate of soda. The addition of sodium nitrate did not affect the insecticidal value of the lime-sulphur. These plats yielded 98.052 and 98.511 per cent of marketable fruit, respectively. The homemade sodium and potassium sulphur solutions, with the exception of the materials used in Plat III, gave 97.972 to 99.167 per cent of

marketable fruit. Plat III (KOH, 11 pounds, and sulphur, 12.5 pounds), 83.352 per cent, No. 2 commercial sodium sulphid 80.833 per cent, and the unsprayed plats averaged but 60.793 per cent of marketable fruit.

Experiment XXI.

FIELD TESTS OF VARIOUS ARSENICALS COMBINED WITH BORDEAUX MIXTURE ON THE FOLIAGE OF GRAPE.

Several arsenicals in combination with Bordeaux mixture (4–4–50) were tested on grape foliage at the vineyard of William Birkit, of Glenlord, Mich. Two applications were made with a power sprayer, June 23 and July 2, 1914, 50 gallons to the plat.

Plat I (applications 1 and 2), commercial arsenate of lead (powder), 1½ to 50; Plat II (applications 1 and 2), arsenate of calcium, homemade (sodium arsenate crystals, 18 ounces + calcium chlorid to 50); Plat III (applications 1 and 2), arsenate of zinc, homemade (sodium arsenate crystals, 18 ounces + zinc sulphate to 50); Plat IV (application 1), commercial arsenate of calcium (paste), 3 to 50, (application 2) homemade arsenate of calcium (sodium arsenate crystals, 18 ounces + stone lime, 3 pounds to 50); Plat V (application 1), commercial arsenite of zinc (paste), 1¾ to 50 (application 2), commercial arsenite of zinc (powder), 18 ounces to 50.

No foliage injury resulted from the applications of these arsenicals.

SUMMARIZED REVIEW.

ARSENATE OF LEAD.

LABORATORY TESTS.

Used alone.—Arsenate of lead was used throughout the experimental work as a basis of comparison for the other compounds tested. The rapidity of killing was greatest with diplumbic arsenate of lead, while the triplumbic form was the slowest. Arsenate of lead of a mixed diplumbic and triplumbic composition closely approached the effectiveness of the diplumbic form. Commercial arsenate of lead No. 1 (triplumbic) was likewise slower in killing than the other commercial compounds, which were largely diplumbic. In tests with the several forms of arsenate of lead upon tender foliage, the triplumbic, the most insoluble form, was found to be the safest.

With kerosene emulsion.—Arsenate of lead may be combined with kerosene emulsion for the purpose of combating mandibulate and haustellate insects. Although there is a slight breaking down of the materials, the value of neither material is depreciated when used jointly as a spray. In order to secure the best results, it is advisable not to mix these materials until needed. In a general way this is applicable to the use of most insecticides in combination.

With lime-sulphur.—Triplumbic arsenate of lead combined with lime-sulphur solution again proved to have a slower toxic effect than either di or di and tri arsenates so combined. The triplumbic commercial No. 1 arsenate of lead was again less rapid as a poisoning agent than the commercial products of diplumbic compositions. It was found that the mixing of lime-sulphur and arsenate of lead results in a smaller consumption of foliage than when arsenate of lead is used alone.

FIELD TESTS WITH APPLES.

With lime-sulphur.—Arsenate of lead consistently proved to be the most effective poison tested during the three years of experimentation. Triplumbic arsenate with lime-sulphur did not hold the codling moth in check quite as well as the ordinary commercial (diplumbic) arsenate of lead. Powdered arsenate of lead is equally as effective as the paste form for the control of the codling moth.

LABORATORY AND FIELD TESTS.

With commercial sodium sulphid No. 1.—The value of arsenate of lead is not decreased when combined with sodium sulphid; in fact the sodium arsenate formed is more active as a toxin than lead arsenate. However, field experiments with apples show that this combination is impracticable, owing to the frequency of foliage injury due to the formation of the soluble sodium arsenate.

With commercial barium tetrasulphid.—Arsenate of lead mixed with barium tetrasulphid was used with satisfactory results for the control of the codling moth. This combination was found safe for use on apple foliage.

With nicotine solutions and lime-sulphur.—Arsenate of lead may be mixed with nicotine solutions and lime-sulphur for the control of certain apple sucking and chewing insects, as well as fungous diseases. The mixing of these materials does not lessen their individual value and moreover may be applied to apple foliage with safety.

With kerosene emulsion and lime-sulphur.—The combination of lead arsenate, kerosene emulsion, and lime-sulphur should not be used as an orchard spray, owing to the breaking down of the materials and the subsequent foliage injury.

With fish-oil soap and lime-sulphur.—The combination of arsenate of lead, fish-oil soap, and lime-sulphur is not a compatible mixture for spraying purposes, since an insoluble calcium soap is formed. In our experience, any combination containing lime-sulphur and soap should not be used.

ARSENATE OF CALCIUM.

An effort was made to secure a satisfactory substitute for arsenate of lead, a compound which would be as efficient and at the same time less costly. With this object in view arsenate of calcium was used

in the experimental work during 1912, 1913, and 1914, and has given encouraging results. This arsenical can undoubtedly be manufactured at a somewhat cheaper cost than arsenate of lead. It is of further interest to note that this compound may be readily prepared at home by combining fused sodium arsenate with stone lime. (For a discussion of the method of making, see p. 30.) While it would be preferable to use arsenic acid in place of sodium arsenate, this acid can not be readily secured at low cost at the present time. When arsenic acid is used the method of preparation as described should be modified somewhat.

LABORATORY TESTS.

Used alone.—Arsenate of calcium, commercial powder and paste and homemade paste, in accordance with several formulas, was used in poison-feeding tests with several species of chewing insects. In some instances the rapidity of killing was equal to that of arsenate of lead, but was generally somewhat less.

With lime-sulphur.—With lime-sulphur, arsenate of calcium was as a rule more effective as a poisoning agent than when used alone. When these compounds are combined, the amount of foliage consumed by the larvæ is less than when arsenate of calcium is used alone.

FIELD TESTS WITH APPLES.

With lime-sulphur.—During the years 1912 and 1913 the several forms of arsenate of calcium combined with lime-sulphur gave fairly satisfactory control of the codling moth, considering the strength of the arsenical used. In 1914 a commercial arsenate of calcium (paste), arsenic oxid 18.82 per cent, combined with lime-sulphur solution, gave very excellent control of the codling moth in comparison with arsenate of lead and unsprayed plats; arsenate of calcium, 29,269 apples, 98.79 per cent sound; arsenate of lead, 24,018 apples, 99.44 per cent sound; unsprayed, 47,866 apples, 58.71 per cent sound. It is of further interest to note that arsenate of calcium may be combined with lime-sulphur without lessening the value of the latter as a fungicide.

FIELD TESTS WITH GRAPE.

With Bordeaux mixture.—Commercial arsenate of calcium and homemade compounds were used combined with Bordeaux mixture in vineyard experiments. These combinations caused no foliage injury.

ARSENATE OF IRON.

LABORATORY AND FIELD TESTS.

Arsenate of iron is a slower acting poison than many of the other arsenicals tested. Laboratory tests, even at increased strengths, show that this arsenical is not quick to kill. In the field tests at the

experimental apple orchard arsenate of iron was not an effective insecticide for the codling moth. When used at greater strengths, however, this arsenical should give fairly satisfactory results, but would have no advantages over arsenate of lead.

ARSENATE OF ZINC.

LABORATORY AND FIELD TESTS.

Arsenate of zinc was used with very fair success in laboratory and field tests, but fell somewhat below the efficiency of arsenate of lead. This arsenical has no distinct advantages over arsenate of lead.

ARSENITE OF LIME.

LABORATORY AND FIELD TESTS.

Arsenite of lime is an active and relatively cheap arsenical poison. Unfortunately, however, its use is frequently attended with injury to the foliage.

ARSENITE OF ZINC.

LABORATORY AND FIELD TESTS.

Arsenite of zinc was used in both the paste and powdered forms alone and combined with fungicides. In common with other arsenites the zinc compound is an active poison, but frequently causes foliage injury. Arsenite of zinc combined with milk of lime and arsenite of zinc mixed with lime-sulphur caused considerable burning in the experimental apple orchard during 1912. In 1914 arsenite of zinc (paste) added to slaking lime and then mixed with lime-sulphur solution gave practically no foliage injury, but the value of the arsenical was apparently impaired. Arsenite of zinc (paste) added to slaking lime for Bordeaux mixture gave excellent codling-moth control and caused no foliage injury. It is possible that the latter combination may be of value in sections where apple growers use Bordeaux mixture along with an arsenical for the control of the codling moth, bitter-rot, and blotch. Commercial arsenite of zinc in combination with Bordeaux mixture was tested in a vineyard during the season of 1914, with satisfactory results.

MISCELLANEOUS ARSENICALS.

The following arsenical compounds were also tested at the laboratory: Arsenic sulphid, arsenic tersulphid, and arsenic trioxid. These materials are destructive to leaf tissue and therefore undesirable insecticides.

Nonarsenical Compounds.

Several compounds containing no arsenic were tested, namely, barium chlorid, barium sulphate, calcium chlorid, copper oxid, lead acetate, lead carbonate, lead chromate, lead oxid, lead peroxid,

mercury bichlorid, zinc chlorid, zinc oxid, and zinc sulphate. While some of these compounds gave more or less satisfactory results, they were not of sufficient promise to warrant further testing.

SODIUM AND POTASSIUM SULPHUR SOLUTIONS.

Caustic soda and caustic potash (homemade and commercial) were combined with sulphur for the control of the San Jose scale. Certain of the solutions proved to be generally satisfactory as scalecides, in some instances equaling lime-sulphur solution. Such solutions can be readily prepared at home without the use of heat.

CONCLUSIONS.

During the course of the experimental work information on the value of many compounds and combination sprays has been secured. Several of the materials proved to be less valuable than those now in common use, owing to their slow killing effect, to their injury to foliage, to their cost, or to their incompatibility. While many of the compounds proved to be impracticable for insecticidal purposes, certain new spray materials and combinations were used with success. Since the prevention of fungous diseases is intimately associated with insect control, many of the insecticides were tested with a fungicide in order to ascertain the results of such a combination.

Arsenate of lead proved to be the most consistent and valuable stomach poison tested, giving satisfactory results throughout the experimental work.

Arsenate of lead is equally effective in either the paste or powdered form.

Triplumbic arsenate of lead is less rapid as a poisoning agent than diplumbic arsenate, but is safer for use on tender foliage.

Arsenate of lead may be combined with nicotine solutions and lime-sulphur solution for the control of certain apple chewing and sucking insects, and fungous diseases.

For the control of certain sucking and chewing insects arsenate of lead may be combined with kerosene emulsion.

Arsenate of lead, kerosene emulsion, and lime-sulphur is an incompatible mixture, due to the formation of an insoluble calcium soap and the subsequent release of free kerosene. In our experience any combination containing lime-sulphur and soap should not be used, owing to the formation of an insoluble calcium soap.

Arsenate of lead should not be mixed with sodium sulphid compounds, since the soluble sodium arsenate formed is destructive to leaf tissue.

Arsenate of lead combined with a commercial barium tetrasulphid gave satisfactory control of the codling moth and caused no foliage injury in the experimental apple orchard.

The most promising new insecticide developed during the course of the experimental work is arsenate of calcium. This arsenical may be manufactured at less cost than arsenate of lead or may be readily prepared at home as described on page 30. During the seasons of 1912 and 1913 arsenate of calcium gave encouraging results. In 1914 a commercial arsenate of calcium paste in combination with lime-sulphur gave very satisfactory control of the codling moth. While arsenate of calcium may have certain limitations, it will doubtless prove of value for the control of chewing insects on certain host plants.

Arsenate of iron and arsenate of zinc are not as satisfactory as arsenate of lead.

Arsenite compounds are dangerous to use on tender foliage. In some instances, however, it may be possible to prevent foliage injury somewhat by combining the soluble arsenic with lime.

Sodium-sulphur and potassium-sulphur compounds gave fairly satisfactory control of the San Jose scale, in some instances equaling lime-sulphur solution. They may readily be prepared at home without the use of heat.

KEY TO THE TABLES OF INSECTICIDES AND COMBINATION SPRAYS USED IN THIS BULLETIN.

[Com=commercial; c. p.=chemically pure; h. m.=homemade.]

Reference.	Table.
Anthracene emulsion	XI, XV
Anthracene emulsion, arsenate of lead (powder)	XI
Arsenate of calcium (com. paste)	VI, XIII, XIV
Arsenate of calcium (com. paste), kerosene emulsion	XIII
Arsenate of calcium (com. paste), lime-sulphur	VI, X, XIII, XIV, XVI
Arsenate of calcium (com. powder)	VIII, XI, XIII, XIV
Arsenate of calcium (com. powder), kerosene emulsion	XI
Arsenate of calcium (com. powder), lime-sulphur	XIV
Arsenate of calcium (c. p. powder)	I, III, V
Arsenate of calcium (c. p. powder), lime	V
Arsenate of calcium (c. p. powder), lime-sulphur	II, IV, V
Arsenate of calcium (h. m. paste)	VI, VIII, IX, XIII, XIV
Arsenate of calcium (h. m. paste), Bordeaux mixture	XII
Arsenate of calcium (h. m. paste), Bordeaux mixture, nicotine sulphate	XII
Arsenate of calcium (h. m. paste), kerosene emulsion	XIII
Arsenate of calcium (h. m. paste), lime-sulphur	VI, X, XIII, XIV
Arsenate of calcium (h. m.), self-boiled lime-sulphur	XIII
Arsenate of iron (c. p. powder)	I, III, V
Arsenate of iron (c. p. powder), lime	V
Arsenate of iron (c. p. powder), lime-sulphur	II, IV, V
Arsenate of iron (h. m. paste)	I, III, V
Arsenate of iron (h. m. paste), lime	V
Arsenate of iron (h. m. paste), lime-sulphur	II, IV, V
Arsenate of lead (com. paste)	I, III, V, VI, VII, VIII, IX, XIII, XIV, XV
Arsenate of lead (com. paste), barium tetrasulphid	XVIII
Arsenate of lead (com. paste), kerosene emulsion	XIII

Table.
Arsenate of lead (com. paste), laundry soap, nicotine sulphate XV
Arsenate of lead (com. paste), lime V
Arsenate of lead (com. paste), lime-sulphur ..... II, IV, V, VI, X, XIII, XIV, XVI, XVII, XVIII
Arsenate of lead (com. paste), nicotine sulphate XV
Arsenate of lead (com. paste), nicotine sulphate, lime-sulphur XV
Arsenate of lead (com. paste), self-boiled lime-sulphur XIII
Arsenate of lead (com. paste), sodium sulphid (com.) XVIII
Arsenate of lead (com. paste), sodium sulphid (com.), lime XVIII
Arsenate of lead (com. powder) ..... VIII, XI, XII
Arsenate of lead (com. powder), anthracene emulsion XI
Arsenate of lead (com. powder), barium tetrasulphid XII
Arsenate of lead (com. powder), kerosene emulsion XI
Arsenate of lead (com. powder), lime-sulphur ..... XII, XVII
Arsenate of lead (com. powder), sodium sulphid (com.) XII
Arsenate of lead (com. powder), sulphur (com. precipitated) XVIII
Arsenate of lead (diplumbic powder) ..... I, III, V
Arsenate of lead (diplumbic powder), lime V
Arsenate of lead (diplumbic powder), lime-sulphur ..... II, V
Arsenate of lead (di and triplumbic powder) ..... I, III, V
Arsenate of lead (di and triplumbic powder), lime V
Arsenate of lead (di and triplumbic powder), lime-sulphur ..... II, V
Arsenate of lead (triplumbic powder) ..... I, III, V
Arsenate of lead (triplumbic powder), lime V
Arsenate of lead (triplumbic powder), lime-sulphur ..... II, IV, V
Arsenate of lead (triplumbic com. paste) ..... I, III, V
Arsenate of lead (triplumbic com. paste), lime V
Arsenate of lead (triplumbic com. paste), lime-sulphur ..... II, IV, V
Arsenate of zinc (c. p. powder) ..... I, III, V
Arsenate of zinc (c. p. powder), lime V
Arsenate of zinc (c. p. powder), lime-sulphur ..... II, V
Arsenate of zinc (h. m. paste) ..... I, III, V, VIII, IX
Arsenate of zinc (h. m. paste), lime V
Arsenate of zinc (h. m. paste), lime-sulphur ..... II, IV, V, X, XVIII
Arsenic sulphid ..... I, III, V
Arsenic sulphid, lime-sulphur II
Arsenic tersulphid ..... I, III, V
Arsenic tersulphid, lime-sulphur II
Arsenic trioxid ..... I, III, V
Arsenic trioxid, lime-sulphur II
Arsenite of lime (h. m. paste) ..... I, III, V
Arsenite of lime (h. m. paste), lime V
Arsenite of lime (h. m. paste), lime-sulphur ..... II, IV, V
Arsenite of zinc (com. paste) ..... I, III, V
Arsenite of zinc (com. paste), Bordeaux mixture XVIII
Arsenite of zinc (com. paste), lime V
Arsenite of zinc (com. paste), lime, lime-sulphur XVIII
Arsenite of zinc (com. paste), lime-sulphur ..... II, IV, V
Arsenite of zinc (com. powder) ..... I, III, V, VIII, IX, XI
Arsenite of zinc (com. powder), kerosene emulsion XI
Arsenite of zinc (com. powder), lime V
Arsenite of zinc (com. powder), lime-sulphur ..... II, IV, V, X
Arsenite of zinc (c. p. powder) ..... I, III, V

	Table.
Arsenite of zinc (c. p. powder), lime	V
Arsenite of zinc (c. p. powder), lime-sulphur	II, V
Barium chlorid	I
Barium chlorid, lime-sulphur	II
Barium sulphate	I
Barium sulphate, lime-sulphur	II
Barium tetrasulphid (com.)	XII
Barium tetrasulphid (com.), arsenate of lead (com. paste)	XVIII
Barium tetrasulphid (com.), arsenate of lead (com. powder)	XII
Bordeaux mixture, arsenate of calcium (h. m. paste)	XII
Bordeaux mixture, arsenate of calcium (h. m. paste), nicotine sulphate	XII
Bordeaux mixture, arsenite of zinc (com. paste)	XVIII
Calcium chlorid	I
Calcium chlorid, lime-sulphur	II
Copper oxid	I
Copper oxid, lime-sulphur	II
Kerosene emulsion	XI, XIII, XV
Kerosene emulsion, arsenate of calcium (com. paste)	XIII, XV
Kerosene emulsion, arsenate of calcium (com. powder)	XI
Kerosene emulsion, arsenate of calcium (h. m. paste)	XIII
Kerosene emulsion, arsenate of lead (com. paste)	XIII, XV
Kerosene emulsion, arsenate of lead (com. powder)	XI
Kerosene emulsion, arsenite of zinc (com. powder)	XI
Lead acetate	I
Lead acetate, lime-sulphur	II
Lead carbonate	I
Lead carbonate, lime-sulphur	II
Lead chromate (com. powder)	I, VII, VIII, IX
Lead chromate (com. powder), lime-sulphur	II
Lead chromate (h. m. paste)	VII, VIII
Lead oxid	I
Lead oxid, lime-sulphur	II
Lead peroxid	I
Lead peroxid, lime-sulphur	II
Lime, arsenate of calcium (c. p. powder)	V
Lime, arsenate of iron (c. p. powder)	V
Lime, arsenate of iron (h. m. paste)	V
Lime, arsenate of lead (com. paste)	V
Lime, arsenate of lead (com. paste), sodium sulphid (com.)	XVIII
Lime, arsenate of lead (diplumbic powder)	V
Lime, arsenate of lead (di and triplumbic powder)	V
Lime, arsenate of lead (triplumbic powder)	V
Lime, arsenate of lead (triplumbic paste)	V
Lime, arsenate of zinc (c. p. powder)	V
Lime, arsenate of zinc (h. m. paste)	V
Lime, arsenite of lime (h. m. paste)	V
Lime, arsenite of zinc (com. paste)	V
Lime, arsenite of zinc (com. paste), lime-sulphur	XVIII
Lime, arsenite of zinc (com. powder)	V
Lime, arsenite of zinc (c. p. powder)	V
Lime, paris green	V
Lime-sulphur	II, V, XII, XIV, XIX, XX
Lime-sulphur, arsenate of calcium (com. paste)	VI, X, XIII, XIV, XVI

Table.
Lime-sulphur, arsenate of calcium (com. powder)..... XIV
Lime-sulphur, arsenate of calcium (c. p. powder)..... II, IV, V
Lime-sulphur, arsenate of calcium (h. m. paste)..... VI, X, XIII, XIV
Lime-sulphur, arsenate of iron (c. p. powder)..... II, IV, V
Lime-sulphur, arsenate of iron (h. m. paste)..... II, IV, V
Lime-sulphur, arsenate of lead (com. paste)..... II, IV, V, VI, X, XIII, XIV, XVI, XVII, XVIII
Lime-sulphur, arsenate of lead (com. paste), nicotine sulphate..... XV
Lime-sulphur, arsenate of lead (com. powder)..... XII, XVII
Lime-sulphur, arsenate of lead (diplumbic powder)..... II, V
Lime-sulphur, arsenate of lead (di and triplumbic powder)..... II, V
Lime-sulphur, arsenate of lead (triplumbic powder)..... II, IV, V
Lime-sulphur, arsenate of lead (triplumbic com. paste)..... II, IV, V
Lime-sulphur, arsenate of zinc (c. p. powder)..... II, V
Lime-sulphur, arsenate of zinc (h. m. paste)..... II, IV, V, X, XVIII
Lime-sulphur, arsenic sulphid..... II
Lime-sulphur, arsenic tersulphid..... II
Lime-sulphur, arsenic trioxid..... II
Lime-sulphur, arsenite of lime (h. m. paste)..... II, IV, V
Lime-sulphur, arsenite of zinc (com. paste)..... II, IV, V
Lime-sulphur, arsenite of zinc (com. paste), lime..... XIX
Lime-sulphur, arsenite of zinc (com. powder)..... II, IV, V, X
Lime-sulphur, arsenite of zinc (c. p. powder)..... II, V
Lime-sulphur, barium chlorid..... II
Lime-sulphur, barium sulphate..... II
Lime-sulphur, calcium chlorid..... II
Lime-sulphur, copper oxid..... II
Lime-sulphur, lead acetate..... II
Lime-sulphur, lead carbonate..... II
Lime-sulphur, lead chromate (com. powder)..... II
Lime-sulphur, lead oxid..... II
Lime-sulphur, peroxid..... II
Lime-sulphur, mercury bichlorid..... II
Lime-sulphur, nitrate of soda..... XIX, XX
Lime-sulphur, Paris green..... V
Lime-sulphur, zinc chlorid..... II
Lime-sulphur, zinc oxid..... II
Lime-sulphur, zinc sulphate..... II
Mercury bichlorid..... I
Mercury bichlorid, lime-sulphur..... II
Nicotine sulphate..... XV
Nicotine sulphate, arsenate of lead (com. paste)..... XV
Nicotine sulphate, arsenate of lead (com. paste), laundry soap..... XV
Nicotine sulphate, arsenate of lead (com. paste), lime-sulphur..... XV
Nicotine sulphate, laundry soap..... XV
Nitrate of soda, lime-sulphur..... XIX, XX
Paris green..... V
Paris green, lime..... V
Paris green, lime-sulphur..... V
Potassium sulphid (h. m.)..... XIX, XX
Self-boiled lime-sulphur, arsenate of calcium (h. m. paste)..... XIII
Self-boiled lime-sulphur, arsenate of lead (com. paste)..... XIII
Soap (fish oil)..... XV

	Table.
Soap (laundry)	XV
Soap (laundry), arsenate of lead (com. paste)	XV
Soap (laundry), arsenate of lead (com. paste), nicotine sulphate	XV
Soap (laundry), nicotine sulphate	XV
Soap (naphtha)	XV
Sodium sulphid (com.)	XII, XIX, XX
Sodium sulphid (com.), arsenate of lead (com. paste)	XVIII
Sodium sulphid (com.), arsenate of lead (com. paste), lime	XVIII
Sodium sulphid (com.), arsenate of lead (com. powder)	XII
Sodium sulphid (h. m.)	XIX, XX
Sulphur (com. precipitated), arsenate of lead (com. powder)	XVIII
Zinc chlorid	I
Zinc chlorid, lime-sulphur	II
Zinc oxid	I
Zinc oxid, lime-sulphur	II
Zinc sulphate	I
Zinc sulphate, lime-sulphur	II

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INSECTS.

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 293

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER October 7, 1915

THE GRASSHOPPER OUTBREAK IN NEW MEXICO DURING THE SUMMER OF 1913.[1]

By HARRISON E. SMITH,
Entomological Assistant, Cereal and Forage Insect Investigations.

INTRODUCTION.

Of the several important grasshopper outbreaks in the United States during the summer of 1913 that of the so-called long-winged

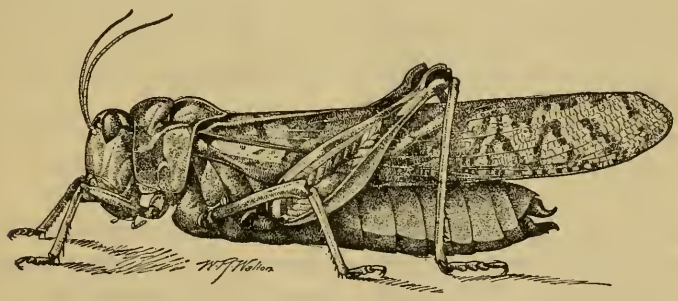

FIG. 1.—Long-winged grasshopper (*Dissosteira longipennis*): Adult female. About one-third enlarged. (Original.)

grasshopper (fig. 1) in the Pecos Valley of New Mexico proved one of the most interesting. Though more or less important outbreaks of this grasshopper have been reported heretofore, very little actual data pertaining to this species appears to have been assembled.

The writer, under the direction of F. M. Webster, in charge of cereal and forage insect investigations of the Bureau of Entomology, spent the month of June, 1913, in the field investigating this rather unusual invasion.

The data are of necessity in certain phases somewhat incomplete since the investigations were carried on entirely under field conditions, although a very considerable amount of information relative to this species was obtained and is herein presented.

[1] The grasshopper discussed in this paper is scientifically known as *Dissosteira longipennis* Thomas; synonym, *Oedipoda nebracensis* Bruner.

HISTORY IN AMERICA.

This long-winged grasshopper was originally described by Cyrus Thomas in 1872 under the name of *Oedipoda longipennis*, from a male specimen, marked "Kansas," submitted to him in a collection from the Agricultural Department. C. V. Riley claims to have collected this species in Colorado on his first trip to that State in 1867.

In 1876 S. H. Scudder proposed a new genus (Dissosteira) for the reception of *Oedipoda longipennis* Thom. and *Gryllus carolina* Linn., designating the latter species as the genotype.

In 1875 Philip R. Uhler found this species in small numbers in the region west of Colorado Springs, Colo.

In 1891 Lawrence Bruner, while upon a general tour of observation to investigate rumored grasshopper ravages in different parts of the Western States, stated that the species causing the alarm in Colorado was "* * * a rather rare species, known as *D. longipennis*, it occurring at that time over 400 sq. miles of territory in sufficient numbers to materially injure the grasses growing on the range of the entire region. Grains and other cultivated plants did not appear to be especially attractive to it. In fact, very little or no injury was done by it to the cultivated crops growing within the region infested."

Between July 10 and 19, 1891, the late E. H. Popenoe visited Lincoln County, Colo., where grasshoppers of this species were so numerous as to stop the trains.

In 1892 Kellogg stated that this species was locally hurtful in Kansas, but that no serious crop destruction was threatened. He stated further, "* * * This locust is a nonmigratory form, occasionally abundant on the plains of eastern Colorado. It sometimes occurs in sufficient numbers in restricted areas to destroy all vegetation."

In 1895 Bruner noted this species "* * * Out on the plains away from the foothills and irrigating ditches," as quite abundant over a large portion of Colorado and Nebraska. He believed "* * * stony hillsides furnished a suitable place for the increase of *D. longipennis* and several other barren-ground species."

In 1896 Bruner again noted this species abundant in Colorado and Nebraska, recording it attacking and actually destroying entire fields of small grains, some corn, potatoes, and a number of garden plants.

In 1898 this species was occasionally noted in western Kansas by S. J. Hunter, who stated that in Edwards County this locust was abundant in a portion of an alfalfa field of 320 acres. This was first observed July 6. On September 1 females of this species were seen ovipositing in this field. It was his opinion that this colony

was bred and reared upon this ground. In the same year he also recorded: "On the evening of July 21 the locusts came from the west down into Colorado Springs in countless numbers."

In 1900 this insect invaded the town of Las Vegas, N. Mex., in great numbers and crushed specimens were everywhere seen on the sidewalks.

In 1904 Bruner wrote, regarding this species, "A native of the high prairies of western Kansas, Nebraska, eastern Colorado, and Wyoming; not nearly so abundant as it was five years ago."

The 1913 outbreak of this species extended over 400 to 500 square miles, the prairie grasses, grain, and garden crops within this area being in great part devastated. Herds of cattle usually grazing within this infested area were forced to travel from 11 to 13 miles for grazing facilities, and would return to their usual watering places only at intervals, varying from 24 to 56 hours. Freight and passenger trains were repeatedly stopped by grasshoppers massing upon the railroad tracks, this being frequent from the middle of May until the first of July.

The prairie grasses within the infested area were so completely ravaged that hardly a surface depression of the soil could be located which was not from one-fourth to completely filled with grasshoppers' droppings.

DISTRIBUTION.

This species is native to the western United States. Since Thomas described the species from western Kansas it has been found in Colorado, Wyoming, Nebraska, Idaho, New Mexico, Texas, and Oklahoma.

SEASONAL HISTORY.

The eggs of this species in New Mexico evidently commence to hatch en masse during the first week of May, though a few nymphs may probably appear during the latter part of April.

Adults were first noted on June 4, and by June 24 the majority of the grasshoppers were in the adult stage. However, third and fourth stage nymphs were present in numbers up to the second week in July.

So far as known, this species has but a single generation per year, the eggs being deposited during late August and early September.

A MIGRATORY OR NONMIGRATORY SPECIES?

In 1892 Kellogg stated that in Kansas this grasshopper is a nonmigratory species.

In 1913, from May 4 to June 24, nymphal droves of this species traveled in a northeasterly direction some 15 to 18 miles, ravaging the entire growth of prairie grasses in their path.

The species is gregarious, the early maturing adults remaining with the nymphal droves until the majority have attained the fully-winged state.

The adults are readily attracted to lights, having been taken at Clovis, N. Mex., during June, 1913, about 25 miles north of Elida, where the main nymphal droves were located at the time.

In the winged state these insects are very wary and are exceptionally strong fliers.

ORIGIN OF OUTBREAK.

This outbreak originated from a tremendous swarm of adults flying from some unknown point to the north. These settled in the outlying districts of Elida, N. Mex., during the latter part of August and early September. During one evening, when swarms of this species were passing over Elida, large numbers of them flew against the plate-glass window of a brilliantly lighted barber shop. The following morning several bushels of dead grasshoppers were heaped on the sidewalk.

BREEDING GROUNDS.

The breeding grounds on which these swarms settled to deposit their eggs were in most part in a chain of sandhills running from about 8 to 10 miles northwest to southwest of Elida. Another considerable swarm settled and deposited eggs in the sandhills 6½ miles southeast of Elida.

On May 4, 1913, at a point 8 miles northwest of Elida, Mr. B. W. Kinsolving noted the tiny grasshoppers coming out of the sand "by the million." Watching this area for a little over a week Mr. Kinsolving says: "Tiny hoppers appeared to be coming out of the sand continually. One evening during a heavy shower certain areas of this breeding ground were covered at least 6 inches deep with tiny hoppers."

On May 6, 1913, 6½ miles southeast of Elida, Mr. Bruce Marsh noted the tiny grasshoppers issuing from the sand in an area nearly 1 mile square, "the ground over this area appearing like a living mass of crawling maggots."

At about the same time the cowboys on the Littlefield ranch, 8½ miles southwest of Elida, noted the sand moving up and down over a great area. When examined they found "countless millions of tiny hoppers crawling to the surface."

Though the major portion of the egg pods were deposited in the sandhills during the fall of 1912, the writer was informed by several parties that some of the eggs, at least, were deposited in hard land. This is very probably true, but at best they constituted a very small percentage.

METHODS OF TRAVEL.

Grasshoppers of this species appear to have a decided preference for massing together and traveling over barren areas, such as roadways, footpaths, and along railroad tracks and right of ways. Over such areas, under favorable weather conditions, immense droves 1 or 2 miles in length, massed closely together, travel along at a rapid gait, all generally traveling in the same direction. Though large droves mass and travel over the prairie proper, the rate of travel is somewhat less than that of the droves passing over barren areas.

Grasshoppers in the third nymphal stage travel at the rate of from 8 to 12 feet per minute; those in the fourth instar from 15 to 20 feet per minute. The rate of travel of nymphs in the first two instars is proportionally less. Nymphal droves of these grasshoppers, under proper weather conditions, travel from 1 to 2 miles a day.

Adults taking flight during a heavy wind fly with the wind, though generally facing it during the rise from the ground to the desired altitude, which usually is from 30 to 40 feet. Adults have been noted to alight on the surface of water and then easily take wing therefrom.

WEATHER CONDITIONS.

Weather conditions are a very important factor in the dispersion of the grasshoppers, at least during that period when the majority are in the nymphal stages.

Throughout the month of June, 1913, the amount of precipitation in New Mexico was greatly in excess of normal.

On dark, cloudy days or during rainy weather the grasshoppers travel very little. Under such conditions they generally collect beneath available shelter, or mass upon the prairie to feed, or slowly wander around with no apparent object in view. If, however, during one of these periods the sun breaks through the clouds to shine brilliantly for a few moments, every individual becomes active and almost immediately the entire drove is rapidly moving along its usual course of travel. The moment the sun disappears travel ceases as promptly as it began, and the former state of inactivity is soon restored.

During fair, bright sunny weather travel usually commences early in the forenoon and continues until the latter part of the afternoon.

Under high prevailing wind conditions the grasshoppers will seek the windward side of any available shelter, there to remain until the wind has ceased or considerably abated.

FEEDING HABITS.

The major portion of the feeding takes place during the early morning hours and the last part of the afternoon, although intermittent feeding is indulged in throughout the day. Under favorable weather conditions the approximate hours of feeding are from daylight until 8 or 9 o'clock in the forenoon, and from 3 to 4 o'clock until sundown during the afternoon. Apparently little or no feeding takes place during the night. The foliage may be entirely devoured or irregular patches cut out from the margin of the leaves. The stems or stalks may be partly or entirely girdled and cut off.

FOOD PLANTS.

Grama grass (*Bouteloua oligostachya*), buffalo grass (*Bulbilis dactyloides*), and mesquite grass (*Bouteloua hirsuta*) are by preference the most relished food plants of this species. Fields of maize, kafir corn, and millet were completely devastated. Millet is in all instances a most desirable food plant. Mr. Hobson, of Elida, informed the writer that he noted the grasshoppers massing in 5 acres of millet on his farm, and in less than 30 minutes every plant had been eaten to the ground. Sorghum is fed upon to a slight extent, but is seldom disturbed if other more desirable food plants are readily available.

Truck crops in the infested area were entirely defoliated, including the following plants: Cultivated mustard, radish, lettuce, squash, sweet potato, young white potato (old plants seldom disturbed), tomato, sweet corn, and immature onion plants.

Under certain conditions Russian thistle (*Salsola tragus*) is readily fed upon, and slight feeding upon soapweed (*Chlorogalum pomeridianum*) has been noted.

Though S. J. Hunter has recorded this species as being abundant in part of a 320-acre tract of alfalfa in western Kansas during 1898, nymphs of this species forwarded to the Wellington, Kans., laboratory, and confined in a Comstock cage placed over alfalfa plants, failed to display any desire for feeding upon this plant, the nymphs ultimately dying from apparent starvation.

PREDACIOUS ENEMIES.

Among the more important bird enemies noted to be feeding upon grasshoppers during this invasion were the desert horned lark (*Otocoris alpestris leucolaema*), western meadowlark (*Sturnella neglecta*),

desert sparrow hawk (*Falco sparverius phalaena*), nighthawk (*Chordeiles virginianus*), killdeer (*Oxyechus vociferus*), and quail (*Colinus virginianus*). The results of further investigations in cooperation with the Biological Survey on the destruction of grasshoppers by birds in New Mexico will be published in another connection.

Several species of lizards, which were very numerous in this locality, fed voraciously upon the nymphs. Oftentimes lizards were noted so bloated from grasshopper feeding that travel was accomplished only with great difficulty. Horned toads were also heavy feeders upon the immature grasshoppers.

While the large droves were passing through the prairie-dog towns these animals appeared to feed upon the grasshoppers in numbers.

PARASITIC ENEMIES.

A dipteron, *Sarcophaga kellyi* Ald., was found to be by far the most important factor in the control of this species, and it was equally efficient as a parasite upon both the nymphs and adults.

Larviposition by the female of *S. kellyi* was continually noted throughout the month of June. The female, as far as observed by the writer, always chose individuals freshly molted or inactive, but in an apparently healthy condition.

During the latter part of June the grasshoppers were enormously reduced in numbers from parasitism by *S. kellyi*. It was a simple matter to count 15 or more dead grasshoppers to the square foot over large areas. The grasshoppers died in such numbers in some localities that ranchers informed the writer that certain droves were almost completely destroyed.

On June 16 a female of *S. kellyi* was noted to deposit tiny maggots on the dorsum of the thorax (pronotum) of a freshly molted nymph. This nymph was captured as the fly finished the act. The fly in question was then noted to rest upon the thorax of a second nymph, where it commenced to larviposit. At this time, while in the act of depositing a maggot, she was captured, and, although badly crushed, the specimen was not so greatly disfigured but that comparison with previously reared specimens proved beyond a question that all were identical. Careful comparison of this female taken in the act of larviposition, with another female noted to be larvipositing in the same manner, but not captured while in the act, proved again that both were the same species.

From the captured nymph above noted six specimens of *S. kellyi* were reared.

This was the only female which the writer was able to capture in the act of depositing the tiny maggots, but it abundantly determined the method of larviposition utilized by *S. kellyi* in parasitizing *D.*

longipennis. Sarcophagids were continually noted to larviposit on nymphs left comatose upon the open prairie, after having been stung by a wasp (*Prionony x atrata* Lep.). In not a single instance was it possible to note a sarcophagid endeavoring to strike a moving nymph or flying adult.

When large numbers of the grasshoppers were molting at approximately the same time the familiar noise of hundreds of female sarcophagids in search of their victim was easily heard. Hot, sunny weather greatly stimulated the activities of the flies, as well as those of the grasshoppers, whereas cold, cloudy, or rainy weather invariably checked them.

The female, upon locating a suitable victim, was observed to alight upon the dorsum of the thorax and quickly deposit several living maggots, which, encountering only the soft, tender membrane, speedily made their way into the body cavity of their host. The maggots are capable, however, of entering a host which is fully dried out and hardened, the writer having noted a female sarcophagid to larviposit on a grasshopper nymph (fig. 2) which had been stung by *Prionony x atrata* and left upon the open prairie beside the partially excavated hole of the wasp; the maggots deposited soon entering the host and the puparia later emerging, to give issuance to adults of *S. kellyi*.

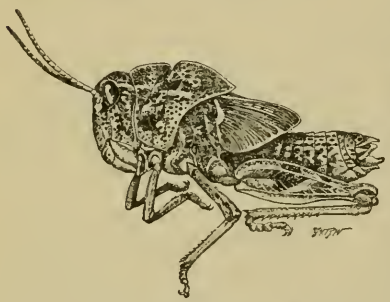

FIG. 2.—Long-winged grasshopper: Nymph which had been stung by the wasp *Prionony x atrata* and on which the parasitic fly *Sarcophaga kellyi* afterwards deposited a larva. About one-third enlarged. (Original.)

The number of living maggots deposited by the female upon an individual host during one period of larviposition would vary from 1 to 7 or more, although from 3 to 6 appeared to be the more general. The writer has reared individuals from five puparia of *S. kellyi* taken from an adult of *Dissosteira carolina* captured at Wellington, Kans., on the wing July 9, 1913, the maggots emerging from the host July 10. As many as 16 maggots have been found in the body cavity of a large nympth of *Hippiscus* sp. in New Mexico.

The maggots of *S. kellyi* usually issue from their host just posterior to the anterior coxa. A certain percentage, however, depart from the host by boring through the abdomen at the segmental sutures or by passing through the anal orifice. Upon leaving the host the maggots may enter the soil directly beneath their victim, or they may crawl several feet away before entering the ground. The summer generations of *S. kellyi* pupate from one-half to 2 inches

below the soil surface, but very probably the maggots or puparia of the hibernating fall generation enter the soil to a much greater depth.

Sarcophaga kellyi is a plural-brooded species, several generations occurring during the season. At least two and probably three generations went through to maturity as parasites of *D. longipennis* from early May to the middle of July.

The grasshoppers will die from the effects of the parasitism while in the act of feeding, and thus they are found hanging to a grass stem, the mandibles firmly attached, in their last dying grasp. The dead grasshoppers lying on the ground may be full of crawling maggots still feeding or endeavoring to issue from their host to enter the soil. When the maggots have emerged from the host only the shell of the grasshopper remains.

Methods of larviposition much similar to those noted by the writer have been recorded by Kunkel d'Herculais on *Sarcophaga clathrata* Meig. in Algiers during 1893–1905. Apparently the foregoing writer had only one species of Sarcophaga involved, as was true in the case of the writer during the present studies.

Second in importance as a controlling factor of *D. longipennis* was the preying upon the nymphs by the sphecid wasps *Prionony x atrata* Lep.

These wasps were always present in large numbers among the hoppers. Being very diligent workers, apparently working from sunrise to sunset during favorable weather conditions, the numbers of the grasshoppers were greatly depleted from their efforts. During the observations of the writer, however, only nymphs were noted to be attacked.

In nearly every instance the single nymph placed in each nest is stung before the excavation is undertaken, but occasionally the burrow will be completed before this is done. However, the female wasps frequently sting several nymphs during the period of constructing a single nest, and in one instance, observed by the writer, as many as five were stung by a single female while excavating an individual burrow. In this case it was the last nymph stung which was drawn into the burrow. The nest finished, the Prionony x flew away, leaving the other four victims lying upon the prairie in a comatose condition. The nymphs once stung by Prionony x seldom, if ever, regain consciousness. This habit, naturally, increases the efficiency of this species.

Usually the hopper is stung in the abdomen, but stinging in the venter of the head regions is common. The wasp, approaching the victim unawares, generally seizes and stings it so quickly that the grasshopper has little opportunity to offer any effective resistance. When a nymph is aware of the presence of a Prionony x it will suddenly assume the very characteristic protective attitude of defense.

Crouching close to the ground, it will raise the posterior pair of legs above the abdomen in the shape of an inverted V, whereupon it will remain perfectly quiet until the wasp has apparently departed. Though the Priononyx will occasionally attack a nymph while in this protective attitude, a severe struggle generally ensues, with the grasshopper infrequently the victor.

A large number of the nymphs which have been stung by Priononyx and left upon the prairie while she is building the nest are in the meantime larviposited upon by *Sarcophaga kellyi.*

The nest is usually built in compact sand. Between railroad tracks and along the right of ways are also desirable nesting places. The excavation of the burrow is commenced by the female rapidly scratching away the surface with the anterior pair of legs. As the depth of the burrow increases the head is cooperatively brought into play with the workings of the anterior legs, when finally the excavation of the burrow is completed by the wasp bringing huge mouthfuls of the soil to the surface. The burrow is excavated almost vertically downward to a depth of 1½ to 2 inches and about one-half inch in diameter. The bottom of the burrow is then excavated in a horizontal direction until a cavity is made sufficiently large conveniently to permit of a nymph being placed within it. In dragging the nymph to the burrow the wasp assumes a horizontal position astraddle the victim. Seizing the nymph with her mandibles at the base of the antennæ, she drags it venter down to the entrance of the burrow. Then facing the nymph, still holding it at the base of the antennæ, she backs into the burrow, dragging in the nymph head foremost behind her. Placing the nymph in the horizontal cavity at the base of the burrow, venter down, in a horizontal position, she deposits a single egg. This egg, white in color, elongate oval, and somewhat curved, is invariably attached to the tender membrane at the base of the posterior coxa.

The egg having been deposited, the wasp proceeds to the surface. Taking a position, back to the burrow, she rapidly scratches the excavated soil into the hole. From time to time she packs down the soil with her head, which she uses as a most efficient ramming instrument. The excavation filled, the wasp carries small sticks, stones, cinders, and the like—these often much heavier than the wasp herself—and places them over the burrow. The time elapsing from the moment the nest is started until its completion usually varies from 30 minutes to 1 hour.

Though it is virtually impossible for the human eye to locate a completed Priononyx nest, there is a bembecid wasp, *Megastizus unicinctus* Say, a secondary upon *Priononyx atrata*, which without the least difficulty locates the Priononyx nest with the greatest exacti-

tude. After Prionony x has completed a nest, a Megastizus will locate it, reexcavate the burrow, and proceed to destroy the egg deposited upon the nymph by the sphecid. This egg is apparently destroyed by the Megastizus crushing it between her mandibles. The Megastizus then deposits upon the nymph an egg of her own.

Megastizus is not particular about refilling the burrow, nor does she attempt to hide the location of it in any manner, as does the Prionony x. Oftentimes Megastizus will leave the nest when the burrow is not more than half refilled with soil. Occasionally the Prionony x will be driven from her nest by Megastizus while in the act of filling up her burrow. Neither Prionony x nor her nest, however, were ever noted to be disturbed by Megastizus until after the prey had been placed in the burrow.

Megastizus never attempted to sting a grasshopper during the present observations, but preyed upon Prionony x entirely, in the rôle of a secondary within the sphecid's nest. Being present in considerable numbers, it most certainly affected the efficiency of Prionony x to a great extent.

ARTIFICIAL REMEDIES.

The most effective artificial means of exterminating the grasshoppers of this species was found in the use of the poisoned bran mash. This was made as follows: Thoroughly mix together in the dry state 25 pounds of wheat bran and 1 pound of Paris green. Into a separate receptacle containing 2 quarts of a cheap molasses or sirup add the juices and finely ground skin and pulp of three oranges or lemons. Dilute the molasses mixture in 2 gallons of water and add to the poisoned bran mixture. Thoroughly mix the two together, adding enough more water, if necessary, to bring all to a stiff dough. This amount of poisoned bait will treat from 5 to 10 acres.

The bait should be sown broadcast early in the morning, before sunrise, in strips 1 rod apart, over the area to be treated. The most satisfactory method of distributing the bait is to sow it from the rear end of a buggy.

In using the poisoned bait as above, with lemons as the fruit employed, tremendous numbers of the grasshoppers were exterminated. As many as 75 dead grasshoppers per square foot were frequently found, several days after the application, over large areas. The grasshoppers usually die from 6 to 80 hours after taking the poisoned bait into the system.

Coarse-flaked brans should be used in preference to the fine-flaked varieties. Only those brands of Paris green which are guaranteed to contain not less than 55 per cent of arsenic should be employed. Arsenate of lead should not be used in any form. There have ex-

isted some differences of opinion as to whether oranges or lemons make the bait more effective. As 75 per cent of the efficiency of the bait is attributed to the use of these citrous fruits, this point is naturally a very important one. The writer, in extensive experiments with different species of grasshoppers, has yet to note any material advantage or marked difference of efficiency in favor of either oranges or lemons.

The Criddle mixture, as commonly employed in grasshopper extermination, was not experimented with during the present investigation for lack of available material. But as nymphs of this species are voracious feeders on horse droppings and dried "cow chips" there seems little question but what this bait could be effectively used if the ingredients were readily available.

On account of the irregularity of the land in the infested area of this outbreak the use of a hopperdozer was not practicable.

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L. O. HOWARD, Chief

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THE ZIMMERMAN PINE MOTH.[1]

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INTRODUCTION.

One of the insects of the order Lepidoptera very destructive to coniferous trees, and especially to yellow pine (*Pinus ponderosa*) in various sections of the West and, according to Zimmerman, Grote, and Kellicott, to white pine (*Pinus strobus*), Canadian or red pine (*P. resinosa*), Austrian pine (*P. austriaca*), Scotch pine (*P. sylvestris*), Swiss pine (*P. cembra*), and other pines in the East, is the Zimmerman pine moth (*Pinipestis zimmermani* Grote[2]). Aside from being largely the cause of "spike-top" (Pl. I) in mature timber, it spike-tops, stunts, and kills outright innumerable trees of the so-called "second growth." The timber of at least one area, thus far discovered, has been brought into such ill repute that carpenters and builders refuse to use it for anything in which "never-ending shrinkage" is objectionable.

Having noted during several seasons the severe injuries inflicted by the larvæ of this insect, the writer, at the suggestion of Dr. A. D. Hopkins, undertook, during the autumn of 1912, a systematic study of its seasonal history and habits, the recorded information on this insect being inadequate. This study was conducted during 1913–14 in conjunction with other work on insects which affect reproduction and

[1] *Pinipestis zimmermani* Grote. [2] Identification by August Busck.

NOTE.—This bulletin is of special interest to manufacturers and users of pine lumber from the Western States.

the development of forest trees, with a view of discovering possible methods of elimination or at least amelioration of its ravages.

Definite details were gathered only in certain areas within the States of Montana and Idaho, but correspondence with the other forest insect field stations in the West, together with larvæ collected and forwarded from those stations, proves that this moth occurs almost everywhere in the West. Considering that Packard records its occurrences in New York and Pennsylvania, it is evident that this insect is probably distributed over most of the United States. Its habits and the result of its larval work also apparently do not vary materially anywhere in its range. These facts lead to the conclusion that the remedy outlined below should be as effective in other regions as in the West.

DESCRIPTION OF THE INSECT.

THE ADULT.

The length of the moth (Pl. II, fig. 1) is about one-half inch. There is no appreciable difference in size and coloration between the two sexes although the general color of individual specimens varies from a light gray to a reddish gray and the body of specimens having the latter hue on head and thorax is usually dark gray. The underside of the entire insect is of a uniform gray color.

The wing expanse is from $1\frac{1}{4}$ to $1\frac{1}{2}$ inches. The fore wings are shaded reddish on the basal and terminal fields, the median space, divided from the latter by W-shaped lines, being blackish and gray, these two colors being again divided by a small white bar on a brownish field.

The hind wings are pale yellowish white, the color becoming deeper toward the terminal fringe, which is paler than that of the fore wings, on which it frequently shades to a dark gray. These characters agree fairly well with Grote's description.

THE LARVA.

When full grown the caterpillar (Pl. II, fig. 2) is about three-fourths of an inch in length. The head is chestnut brown, the mandibles black. The body is naked, with a series of dots, darker than the skin, from each of which issues a single bristle. It has three pairs of thoracic legs, four pairs of abdominal prolegs, and a pair of anal claspers. The body varies greatly in color, which ranges from a dirty white, through reddish yellow, to a vivid green. The larva found in yellow pine is almost invariably gray-brown, resembling the color of the bark of the host tree, while those in Douglas fir are of such a vivid green color that it seems almost incredible that they should be representatives of the same species which infests pine. Rearing them to the adult stage, however, always dispels any doubt in this regard.

Variations in color, about which Grote and Kellicott differ, are evidently merely a matter of host differences.

THE PUPA.

Freshly formed chrysalids are of a light brown color, which changes to blackish brown as the moth within develops toward maturity.

The chrysalis is cylindrical, about three-fourths of an inch long, rather slender, and without spines on the segments. This last character makes it readily distinguishable from a sesiid pupa, which is frequently found under somewhat similar conditions.

SEASONAL HISTORY AND HABITS.

While adults emerge and mate from about May 1 to September 15, the maximum flight of the moths occurs during the month of July. They appear to be rather long lived, many 2-weeks-old specimens reared in the laboratory being as ready to take wing when disturbed as when they had just burst the bonds of the chrysalis. No other species of moths reared in captivity the larvæ of which feed on internal tree tissues were observed to live more than 10 days after emergence under similar conditions. The longevity of the Zimmerman moths evidently extends the period of mating beyond the general flight, and consequently fertilized eggs are deposited during any of the milder months.

Larvæ of all sizes, except the most minute in winter, may be found at any time of the year.

Though frequently but a single larva is found in a wound, the writer is of the firm opinion that eggs are almost invariably deposited in clusters. In the many observations while the larva was less than three-eighths of an inch in length six or more of them were always found in one infested spot. From a specimen of yellow pine 6 inches in length and but 1 inch in diameter showing old work, which was placed in a breeding cage during the middle of December, a month and a half after heavy frost had ended all outdoor insect activity, seven larvæ emerged early in January from eggs which had evidently been deposited on this small specimen during the previous late autumn. (Pl. II, fig. 3.)

Again, it is often the case that a space a foot or more wide and several feet long on a tree trunk has the cambium literally honeycombed with the tunnels of numerous larvæ. In one such case the writer found 27 nearly mature Pinipestis larvæ at work.

In mature stands, in "spike-tops" in the making, and at the bases of new spikes, plural infestation is evidently the rule.

This conclusion is verified to some extent by the observations of Mr. W. D. Edmonston at the Forest Insect Field Stations at Ashland, Oreg., and later at Colorado Springs, Colo., and by quite a number of larvæ and valuable notes that he sent to the writer. These notes generally end with the statement: "Under bark in hardened pitch

were found empty pupa cases," or "Empty chrysalids were found in the pitch masses."

Since no other pitch moth so seriously destructive to the trunks of mature or nearly mature trees leaves the entire pupa shell *within* the bark or the pitch which sheltered the immature insect, its identity is quite easily determined.

The eggs deposited in July appear to hatch within about two weeks. During the latter part of August the young larva manifests its presence in infested trees rather plainly by the mixture of coarse castings and brown bark dust which is thrown out through the entrance and other holes in the bark made by the larva. Unlike the larvæ of the sesiid pitch moths, the pine moth caterpillar does not work into the cambium and stay there. Quite often, if not always, after attaining nearly half its full growth, it leaves the place where it hatched and drills into the tree tissues again at a spot which presumably suits it better, not infrequently several feet away from the original spot. To this migratory habit probably must be attributed the frequent occurrence of but one larva in a wound, except in instances where the work of woodpeckers accounts for their isolation. This assumption seems to be supported by the fact that all such hermits when located are developed well toward maturity.

As the larva grows and the inactive season approaches, this promiscuous gnawing of holes in the bark ceases. In no case even where most of them remain where they first saw the light is migration resumed the following spring. In the spring each larva prepares for pupation in its own individual tunnel, though under the same space of infestation, by lining it with silky thread. Packard states [1] that "the worm in July spins a whitish, thin, papery cocoon in the mass of exuding pitch, which seems to act as a protection to both the larva and the chrysalis." This applies to the insect in the East. In the West the caterpillar of the pine pest restricts its weaving operations before pupating to the above-mentioned lining of the tunnel. Cocoons which answer Packard's description are frequently found in these tunnels, but they are of a parasite which will be referred to later.

On approaching maturity, about the middle of June, the larva grows sluggish and is found to be transformed into the chrysalis within a few hours. When the moth has attained full development, 29 days from the time the pupa was formed and a year after the egg was laid, it merely bursts the chrysalid skin, leaving the empty shell within the tunnel, and pushes its way out through the very thin pitch covering at the mouth of the tunnel. The period of pupation in captivity under very varying temperatures and during all seasons

[1] Packard, A. S., Insects Injurious to Forest and Shade Trees. 5th Rpt. U. S. Ent. Com., 955 p. (p. 731), 38 pl., 306 fig., 1886–1890.

within a period of two years has in all cases proved to be exactly 29 days.

Eggs laid the previous autumn hatch in early spring and develop into adults during August and September of the same year, while eggs deposited during May evidently develop into adults early the following spring.

RELATION TO OTHER INSECTS.

In the northern Rocky Mountain region *Pissodes schwarzi* Hopk.[1] is a common associate of the pine moth in yellow pine, if the trees are attacked near the base. It appears that there the moth takes as frequent advantage of the work of the beetle as the beetle does of the moth's. The result of infestation by either of them is exactly alike, although the latter's attack is by no means restricted to the base of trees, while the work of the beetle is rarely found more than 2 or 3 feet above ground.

Sesia brunneri Busck,[2] wherever it exists (at present known in Montana and southern Idaho), is frequently associated with Pinipestis in yellow and lodgepole pine. While the attack by the Sesia in lodgepole pine appears to invite and to be the cause of subsequent infestation by the Pinipestis, the former frequently takes advantage of the work of the latter in yellow pine greatly to augment its own numbers. When this sesiid moth attacks a tree primarily it invariably deposits but one egg at a spot; but when it infests the pine moth's work in yellow pine it seems always to deposit quite a number of eggs. The writer has taken as many as six nearly mature Sesia larvæ from a single space surrounding a spot previously infested by the pine moth. The space infested by the latter is always killed and subsequent infestation can only occur at the border of such a spot. As the Sesia larva works parallel with the grain of the wood, its infestation of Pinipestis work becomes evident on the surface of the surrounding fresh bark by regular pitch masses of the size of a silver dollar instead of the general pitchiness which characterizes pine pest infestation, owing to the numerous holes it makes in the bark.

If the pine moth reinfests such a Sesia-infested space, its larvæ, feeding on the strictly fresh cambium surrounding it, usually stop the necessary flow of sap to the space occupied by the Sesia and the latter is starved to death on this account. To comprehend how this is possible, it must be understood that the sesiid larva is not able to move around at will on the surface of the bark, that it is apparently unwilling, if not unable, to cross spaces already sapped by other insects, and that it requires two years to complete its life cycle.

Two small moths of the genus Laspeyresia,[3] one in yellow pine and one in Douglas fir, frequently breed in the work of the pine moth in

[1] Identified by A. D. Hopkins.

[2] Busck, August. Descriptions of new microlepidoptera of forest trees. *In* Proc. Ent. Soc. Washington, v. 16, no. 4, p. 143–150, pl. 7–8, 1914.

[3] Identified by August Busck.

considerable numbers. However, the relation seems to be of no economic importance.

In Montana and Idaho another species of Pinipestis, *P. cambiicola* Dyar,[1] is one of the most important factors in regard to the existence of *Pinipestis zimmermani* Grote. It infests during the latter part of June the cambium of the terminal branches of mature yellow pine, and many of these wounds are subsequently reinfested by the latter year after year. The work of this insect is almost invariably the primary cause of the knobby growth on branches in which the Zimmerman pine moth breeds undisturbed by woodpeckers or parasites, and this moth must therefore be regarded as a provider of brood trees for the more destructive *Pinipestis zimmermani*. (Pl. III.)

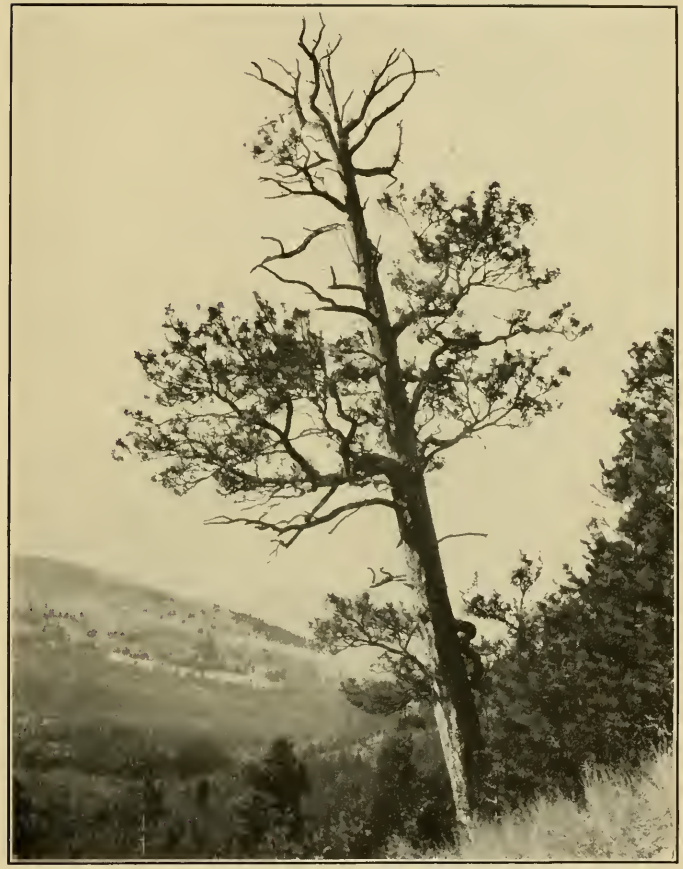
RELATION TO NATURAL ENEMIES.

In most sections of the Rocky Mountains the Rocky Mountain hairy woodpecker (*Dryobates villosus monticola*) is unquestionably the most efficient natural force in restraining the Zimmerman pine moth. Thousands of trees are each year regularly infested by the moth in comparatively small areas, and this bird as regularly destroys almost all of the larvae in all of them during early winter, so that, although hundreds of trees may be examined at a time, it is only on rare occasions that larvæ are found after December in wounds in the trunks of trees which had been infested during the previous summer. This woodpecker seems to have a decided preference for the caterpillar of the pine moth wherever the writer and the entomological rangers assigned to the Northern Rocky Mountain Field Station have had opportunities for observation. In the extreme southeastern part of Montana, and particularly that portion covered by the Northern Cheyenne Indian Reservation and by the Custer National Forest, the moth has apparently neither bird nor insect enemies. In all other localities this woodpecker is fully able to eliminate this insect as a serious factor in timber destruction. Especially will the work of the bird become effective when the habits of the moth are more generally understood and its "brood trees" are eliminated through use by man.

From reports from other field stations the writer concludes that from Idaho west toward the Pacific coast and in the southern Rocky Mountain region woodpeckers are of no consequence as a check upon this insect. But, considering that much confusion still exists concerning the identity of Pinipestis among the "pitch moths," this conclusion may prove erroneous when more thorough information is available.

The woodpecker never molests the caterpillars of the pine moth which live under "spike tops" and in knobby branches on certain

[1] Identified by H. G. Dyar.



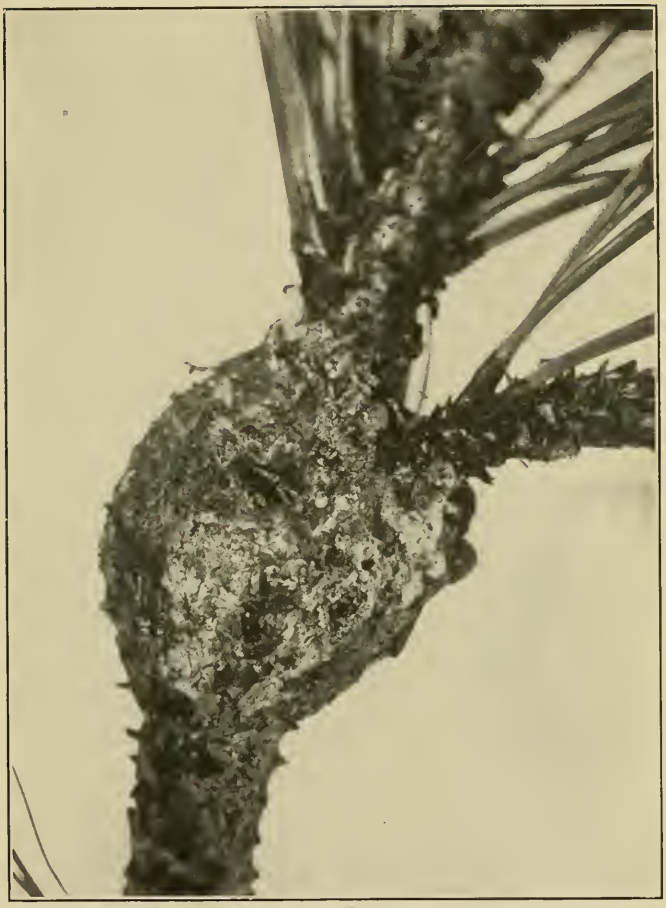
REPEATED INJURY BY THE ZIMMERMAN PINE MOTH TO LARGE TREE, RESULTING IN "SPIKE-TOP." (ORIGINAL.)

FIG. 1.—ADULT MOTH. SLIGHTLY ENLARGED. (ORIGINAL.)

FIG. 2.—LARVA. TWICE ENLARGED. (ORIGINAL.)

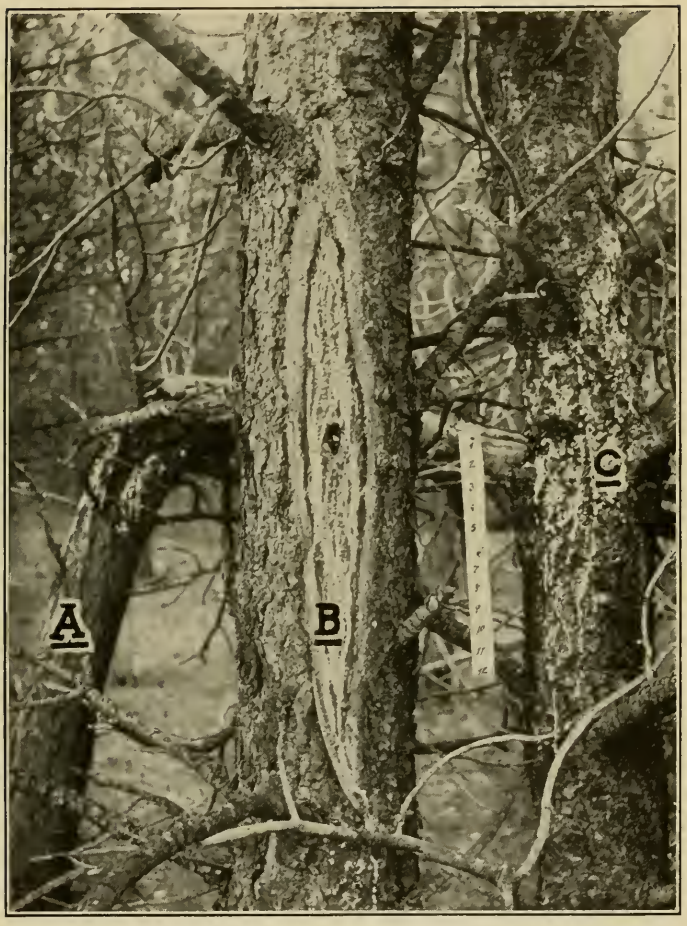
FIG. 3.—MOTH ON SECTION OF TREE TRUNK, SHOWING CHARACTER OF INJURY. SEVEN LARVÆ WERE FOUND IN THE BARK OF THIS SECTION IN DECEMBER. (ORIGINAL.)

THE ZIMMERMAN PINE MOTH (PINIPESTIS ZIMMERMANI) AND ITS WORK.



PINE SHOOT SHOWING PRIMARY INJURY BY PINIPESTIS CAMBIICOLA, AND INFESTATION, TWO YEARS LATER, BY THE ZIMMERMAN PINE MOTH. NATURAL SIZE. (ORIGINAL.)

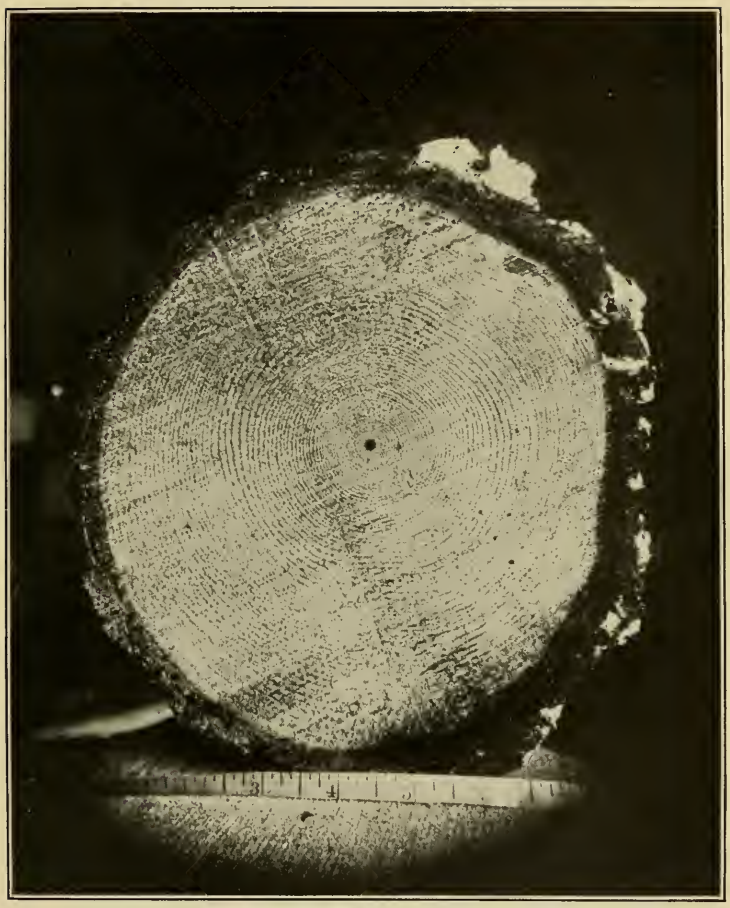
PINE TREE SHOWING RESULT OF REPEATED ATTACK BY THE ZIMMERMAN PINE MOTH, AND THE INJURY AGGRAVATED BY THE ROCKY MOUNTAIN HAIRY WOODPECKER IN ITS SEARCH FOR THE LARVA. (ORIGINAL.)



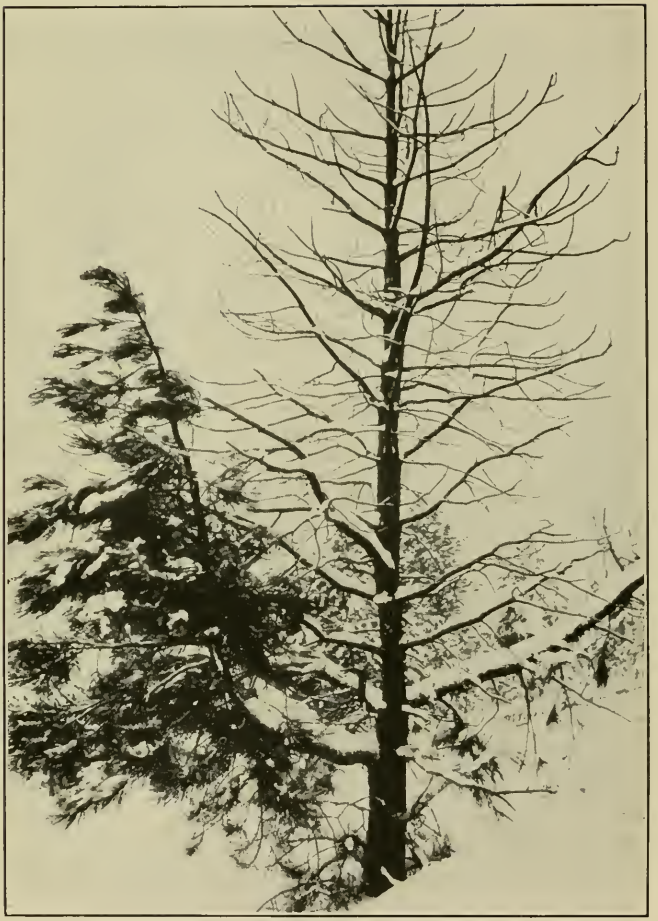
YELLOW PINE SHOWING CHARACTER OF INJURY BY THE ZIMMERMAN PINE MOTH.

A, Tree broken at injury; *B*, tree attacked by insect and insect removed by woodpeckers; *C*, tree girdled and killed by the insect. (Original.)

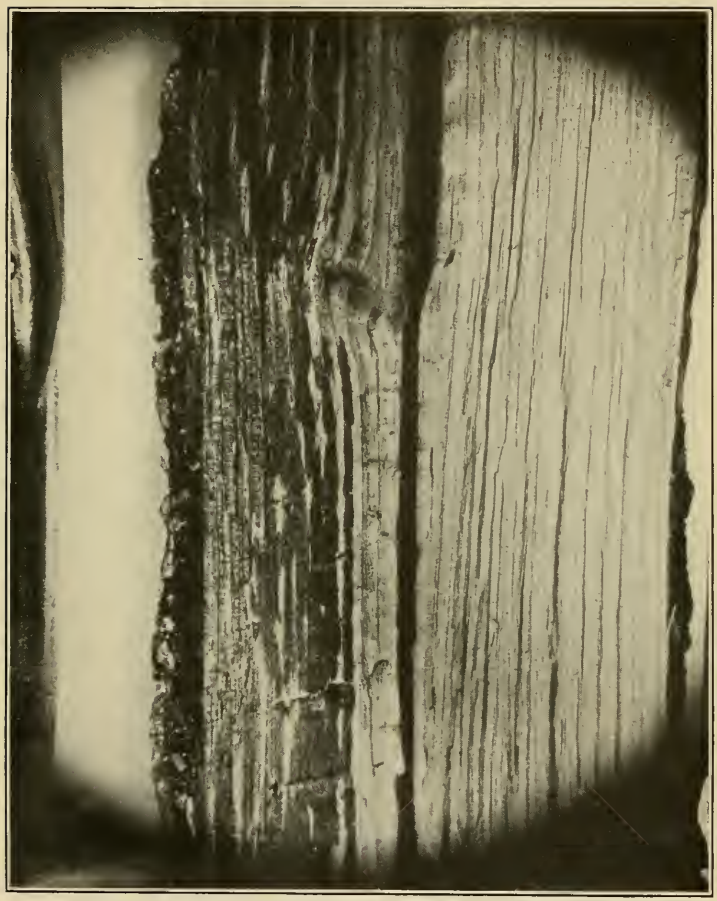
CROSS SECTION OF PINE SAPLING SHOWING EFFECT OF INJURY BY THE ZIMMERMAN PINE MOTH. (ORIGINAL.)



CROSS SECTION OF OLD, SLOWLY-GROWING YELLOW PINE SHOWING INFESTATION BY THE ZIMMERMAN PINE MOTH AND ITS INJURY IN BARK. (ORIGINAL.)



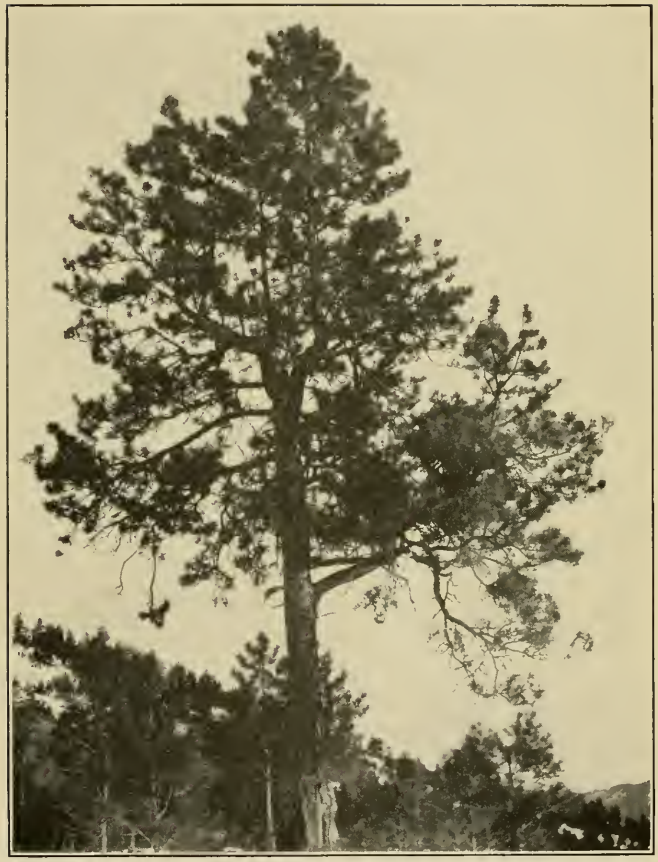
PINE TREE SHOWING EFFECT OF CONTINUOUS INJURY BY THE ZIMMERMAN PINE MOTH. (ORIGINAL.)



LONGITUDINAL SECTION OF YELLOW PINE SAPLING SHOWING RESULTING DAMAGE TO WOOD FROM ATTACK BY THE ZIMMERMAN PINE MOTH. (ORIGINAL.)

FIGS. 1, 2, 3.—TYPICAL YELLOW-PINE "BROOD TREES" OF THE ZIMMERMAN PINE MOTH.

The removal of such trees and the burning of the affected parts is the most effective measure for the control of this pest. (Original.)



OLD YELLOW-PINE TREE SHOWING RESULT OF INJURY TO TOP BY THE ZIMMERMAN PINE MOTH. (ORIGINAL.)

mature trees (see *Pinipestis cambiicola*, p. 6) and this is evidently the reason why its activities bear no permanent fruit. Considering also that the birds in hunting for the larvæ strip the trees of as much bark and cambium as the moth larvæ destroy in one generation, and that this operation is repeated each season, it is doubtful whether the woodpecker cure is not as bad as or even worse than the moth evil, when one considers that the brood trees are allowed to replenish the ranks of the insect year after year. (Pl. IV.)

The cocoon of a pimplinid of a new genus and new species [1] is frequently found in the tunnels of the pine moth in Montana and Idaho. In some localities this parasite kills as many as 80 per cent of the larvæ of the moth in second-growth trees. As the parasite cocoons are not molested by woodpeckers, a full quota of this fly emerges during the first warm days of each spring. While this parasite greatly aids in checking the increase of the moth from larvæ which infest second growth, it fails, as does the woodpecker, to pursue the caterpillars in the above-mentioned brood trees. Hence it is as much of a signal failure as is the bird.

Another, somewhat larger parasite (*Ichneumon* n. sp.[1]) is frequently found during winter in the chrysalis of the moth. The moth does not pass the winter in the pupal stage, and chrysalids found at that time always contain the parasitic fly, which, like the pimplinid, emerges during early spring. It is apparently less numerous than the latter and consequently of still less economic importance.

There seems to be justification for the conclusion that, without man taking a hand by eliminating the main propagating opportunities, no natural enemy of the moth will ever render it harmless. With human aid these agents will accomplish all that can be reasonably expected of them, i. e., the elimination of the ravages in rationally managed woodlands.

HABITAT AND HOST TREES.

Open, sunny stands of timber are those most affected by the Zimmerman pine moth. Slashings, on which reproduction has reached a height of 10 feet or more, having a scattered stand of mature trees, which were left standing to reseed the area or on account of being unfit for logs, invariably contain the greatest amount of pine-moth injury. It appears to be an absolute necessity to the insects' existence in a locality stocked with second growth, that the stand contain some of these specimens, which constitute brood trees for this insect. Where the mature timber has been cut clean over quite large areas, so that the chance for influx from without is remote, the insect does no damage, even though the ground may be stocked with an ideal

[1] Determined by S. A. Rohwer.

stand of second growth. Yellow pine, lodgepole pine, and Douglas fir are the tree species thus far noted to be subject to infestation by this insect in the West. Out of a hundred trees so infested about 80 per cent are yellow pine, 15 per cent lodgepole pine, and 5 per cent Douglas fir. Trees with a thick layer of fresh bark and cambium, as well as the more vigorous growers, are preferred for attack. All sizes, from but a few inches to several feet in diameter, are subject to infestation; but it is the mature trees which furnish the most favorable means of existence for this moth, while in the smaller ones, up to about a foot in diameter, it does the greater damage. (Pl. V.)

CHARACTER OF INJURY AND WORK OF LARVÆ.

The moth, as a rule, attacks mature trees from between 10 to 30 feet from the top down, and second growth from about breast high up to from 35 to 40 feet. Infestation nearer the top or base occurs only to a very limited extent.

As stated under "Seasonal history" (p. 4), fresh infestation is only indicated by the castings on the surface area of the attacked trees. If this area is very heavily infested, as in the case cited above, where the writer found 27 nearly mature larvæ in a space less than 5 feet in length by about 1 foot in width, there is at no time any other indication observable. The bark dries up without exuding pitch, as if scorched by extreme heat, and several years after the insect has vacated the bark drops off and the injury becomes manifest to the average passer-by. Usually, however, in such cases some larvæ leave the point originally infested and bury themselves higher up near a branch of the same tree. The pitch tube at the entrance of this tunnel invites close examination of the entire tree, whereupon the less conspicuous, yet heavy infestation is almost sure to be detected. (Pls. VI and VII.)

During the spring following infestation drops of pitch usually begin to ooze out of the tunnels in the bark and cover the surface of the average wound with a uniform, thin layer, somewhat similar in appearance to a liberal application of paint with a brush. The inner bark assumes a spongy appearance and gains in thickness, which tightens and even breaks the outer bark, together with the dried pitch covering it. The entire infested space finally presents a strikingly rough aspect which resembles the injury of no insect except *Pissodes schwarzi*, which produces a similar effect at the base of trees.

By repeated infestation at the border of the wound, in the course of years the tree is gradually girdled and the part above the collar dies and finally rots off at its base, provided the moth abandons the tree at this stage. But frequently infestation continues downward, on young trees usually until the lower branches, which by that time

show a tendency to develop into tops, are reached and the trees killed, and on mature ones to a point where the thickness of the bark fails to suit the insect. (Pl. VIII.)

On wounds infested by a single larva a pitch tube, resembling that produced by sesiid pitch moths, is usually formed, presumably because one larva alone is not capable of cutting as near the surface as when several work together in one space. In the latter case the tunnels cross and recross continuously, and when a larva strikes the tunnel of another, which must happen frequently, it usually cuts to the surface in order to avoid the solidified pitch. To the presence of the larva so very near and even at the surface of the bark must be attributed its rather heavy parasitization in localities where its parasite exists, because larvæ living singly are very seldom parasitized.

EFFECT OF INFESTATION ON TREE GROWTH AND FOREST.

It is obvious that the killing of many trees in stands preferred by the moth results in too great a thinning out of the stand. This wastage of ground is further augmented by the permanent stunting of a still greater number of trees by the insect's work, because the space taken up by such scrubs would just as readily accommodate thrifty, well-formed trees.

Moreover, the wood from trees that have been infested by the moth is invariably so permeated with pitch that the lumber cut from such logs is either materially reduced in value or is rendered wholly unfit for commercial use. (Pl. IX.) From one part of southeastern Montana, where this moth is especially abundant and a large percentage of the trees are pitch soaked, the lumber is, for this reason, only used for sheds, etc., where shrinkage can be discounted; the users find it cheaper to have the better material shipped in than to pick it out of the local stuff and throw half of it away unless it is needed for the less particular purposes indicated. To the writer this practice at first seemed rather to indicate prejudice against the home product, because there is a large amount of first-grade lumber produced along with the bad. However, the pine moth is responsible for this condition, as was abundantly proved by examination of its injury in the district. The manner in which the moth's work "pitchifies" the wood is best seen in the well-known tops which have been infested by it. From these tops the bark has dropped off, but the surface of the wood has a roughened appearance and the tissues are literally saturated with pitch, while at the lower end, where the infestation ended and the wood was not pitchified in the process, the spike is rotted off from the tree. This insect's work alone accounts for the fact that the extreme top of a tree may be excessively pitchy, while the rest of the same tree is not.

REMEDY.

There is probably no other seriously injurious insect which can be eliminated with less expense and trouble than the Zimmerman pine moth, because practically everywhere, wherever its existence is causing real damage, the country is readily accessible, being either already logged over or adjacent to settled farming land.

In slashings the remedy consists in logging, thus removing the mature trees as soon as the area is reseeded, and in any other wood lot, where it shows its presence in the second growth, in merely using all "spike-topped," lightning-struck, and heavily branched mature trees for firewood or domestic purposes. These are the "brood trees" in the great majority of cases, and their disposal ends the trouble in the growing trees. The larva in these three types is found at the base of the spike, along the scar caused by the bolt, and in the knobby growths on the branches which are the result of primary injury by *Pinipestis cambiicola* (in the West) and probably other insects. The affected parts should be destroyed, the simplest way being to burn them before the arrival of spring. The judicious choosing of the right trees for firewood for home consumption alone would prevent on many farms further damage by this insect to the growing trees. In one wood lot east of Missoula, Mont., covering about 40 acres of a quarter-section farm, 25 per cent of the second growth had been infested annually for several seasons, and the cutting of only three overmature trees during 1913–14 for firewood ended the damage absolutely. One of them was a still infested spike-top and two were full of knobby branches, also infested. There are still about 80 overmature trees standing on that farm, but the three cut were evidently, as supposed before the cutting, the only "brood trees," and, as the woodpeckers had taken care of the infestation in second-growth trees, the elimination of the moth at that place was a natural result of the disposal of these trees. (Pls. X and XI.)

In a locality about 5 miles north of Missoula, Mont., where at least 3,000 second-growth trees are infested and reinfested annually, the writer is positive that the cutting of not more than 24 overmature "brood trees" in a stand of about 1,000 of the same age as these would effectively end the continuous depreciation. In other localities not so thoroughly examined, the proportion of work necessary to end the trouble appears to average about the same. Even in southeastern Montana, though the moth is not subject there either to woodpeckers or parasites, the insect damage could be greatly reduced, if not eliminated, by disposing of the "brood trees" by merely selecting them for fuel.

CONCLUSION.

It is evident that natural agencies have not succeeded in preventing, and will not be able in the future to prevent, serious damage by this moth unless man aids their efforts by disposing of such trees as have fulfilled their usefulness in the forest and wood lot, and which, instead of being an asset there, have become a menace. To end "spike topping" in mature stands, and to eliminate damage in growing timber, or at least reduce it to a negligible amount, it is necessary to remove (1) those trees which, below the spike, show branches with yellow needles (a certain indication of present infestation), (2) those which are struck by lightning and remain green, as the moth usually breeds in great numbers along the lightning scars, and (3) those which display knobby growths on branches, they being in many localities the most prolific source of replenishment of the moth.

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Pages 731–733. *Nephopteryx* (*Pinipestis*) *zimmermanni* Grote.

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BULLETIN No. 325

Contribution from the Bureau of Crop Estimates
LEON M. ESTABROOK, Chief

Washington, D. C. ▼ November 26, 1915

HONEYBEES: WINTERING, YIELDS, IMPORTS AND EXPORTS OF HONEY.

By Samuel A. Jones, *Chief, Division of Crop Reports.*

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WINTERING OF HONEYBEES, WINTER 1914–15.

The data included in returns from about 650 honey producers in 42 States, covering 80,000 colonies of bees, including full reports from the important honey-producing States, bearing primarily upon the wintering of bees and showing the losses and causes thereof for the past winter, are summarized in Tables 1 and 2.

While the figures are believed to be fairly representative and trustworthy, this can not be assumed in all cases, as some States producing considerable honey failed to furnish enough reports to give full confidence in the State average.

It will be seen by reference to column 1 that bees entered winter quarters in good condition, notwithstanding the poor season in much of the country. Two factors probably contributed largely to this result, the first being that in States where little surplus honey was stored in the spring and early summer many beekeepers refrained from removing honey from the hives, and the second that the fall nectar flow was generally good, permitting the colonies to build up and affording sufficient supplies for winter.

It will be seen by reference to columns 4 and 5 that the average quantity of honey on hand at the beginning of winter was generally in excess of what was assumed by the beekeepers reporting to be

Note.—This bulletin will be found of interest to beekeepers and dealers in bee products.

9956°—Bull. 325—15

needed to carry a colony through the winter and give it a good start at brood-rearing in the spring.

An interesting circumstance shown by a comparison of the figures in column 4 is that there seems to be little variation between the supply of food required to winter a colony in the different parts of the country, notwithstanding that the period in the Northern States between the fall and spring nectar flows (evidently interpreted by many reporters as the period between honey flows yielding a surplus) is shown in column 2 as from 7 to 9 months, with the bees confined to the hive for as much as 3 or 4 months at a time (column 3) without opportunity for a cleansing flight, while in the Southern States the interval shown between nectar flows is from 4 to 6 months only, and confinement to the hive ranges from a month down to but a few days at a time. The explanation of this uniformity in food requirements under greatly varying conditions is not entirely clear, though the comments accompanying the reports indicate that it may be due in part at least to the greater activity of bees during the winter season as one proceeds southward, the warm days permitting the winter cluster to be frequently broken, with the bees active and flying out. Also in many sections of the South brood-rearing throughout the winter is quite frequent, while in the North colonies which are well cared for and are not compelled to battle with extremely low temperatures are less likely to begin brood-rearing prematurely.

The percentage of the colonies given winter protection, as shown in column 6, *g*, very high in the Northern States, drops off rapidly to almost nothing south of the Potomac and Ohio Rivers and in the Southwestern and Pacific Coast States. In the extreme North a favorite mode of wintering is shown (column 6, *a*) to be in cellars, in the less extreme Northern States mostly by means of double-walled and packed hives (column 6, *b*), while farther south such occasional protection as is given is usually confined to supers packed with absorbent material, to wrappings of tar paper, etc., around the hive, the employment of windbreaks or open sheds, the partial covering of the hive with straw, etc. A number of reports from the Western Plateau States mention the practice of covering all but the entrance of the hive with straw overlaid with earth.

The losses during the past winter, as will be seen by reference to column 7, *j*, Table 2, generally range from 15 to 20 per cent in the more northerly States of the white-clover belt, from 5 to 15 in the lower portions of that belt and in the Southeastern and South-Central States, and in the neighborhood of 5 to 10 per cent in the important honey-producing States of Texas, Colorado, Utah, and California, with but 2 per cent in Arizona. The average for the entire country is 12.6 per cent.

The cause of loss most frequently given is missing or worn-out queens. The most important absolute item of loss is starvation. A serious loss is shown from poor quality of winter stores, usually aster honey, which in some sections, with long confinement, is said to induce dysentery. Late and weak swarms often succumb. Losses of colonies deficient in young bees were heavy in districts where a late summer drought interfered with fall brood-rearing. Various other causes mentioned are smothering and exposure, which have been included with cold, long confinement, robbing, brood disease, mice, moths, ants, and small predatory animals. A considerable percentage of reporters failed to state the cause of death, either from carelessness or perhaps disinclination to mention starvation as the cause. That so many should have been shown to die from the latter cause, which can in a great majority of cases be avoided by moderation in removing surplus honey or absolutely prevented by the proper feeding of sugar sirup in the late fall or early spring, is a regrettable exhibit.

CONDITIONS AND HONEY YIELDS, SEASON 1915.

The number of colonies, spring count, reported this season averages for the entire United States two-tenths of 1 per cent less than last year (Table 3, column 8). Increases of 15 per cent in Texas, 10 per cent in California and Arizona, and rather general increases in the northern tier of States from Michigan westward are offset by decreases of 14 per cent in Missouri, 10 per cent in New York and Indiana, 8 per cent in Illinois, Nebraska, and Arkansas, and smaller percentages in a number of other important honey-producing States.

The condition of the colonies on May 1 (column 9, *a*), largely measured by the number of bees and amount of brood compared with a normal condition of populousness and vigor at that date, was 92.7 per cent for the United States as a whole, being 5.1 per cent lower than on May 1 last year. (See column 9, *b*.) This may be ascribed in part to the late cold spring over much of the country, which delayed brood-rearing, and to some extent to the poor quality of the winter stores in many States, which weakened the colonies.

The condition is shown below 90 in New York, Maryland, Ohio, Illinois, Missouri, Nebraska, Kansas, Oklahoma, and Arkansas, and 90 or slightly above in Pennsylvania, Virginia, Indiana, Iowa, Tennessee, and Alabama. In each of the States named except Kansas it was lower than last year.

The condition of honey plants, shown on May 1 as 93.3 per cent, is 5.8 per cent lower than last season at that date (columns 10, *a*, and 10, *b*.) As weather conditions since May 1 over the country as a whole have been decidedly better for plant growth than last year, when droughty conditions prevailed in many sections, the condition

of most honey plants east of the Rockies improved materially after the date of this inquiry.

The July 1 reports indicated that the honey season had been late from 1 to 3 weeks over most of the country, due to cold and generally wet weather. The prospects in the Ohio Valley region were very poor owing largely to the damage to white clover from former droughts. The crop outlook from clover in the Central Atlantic and New England States and west of the Mississippi was fair to good. The outlook for alfalfa honey in Utah and in sections of adjoining States was unfavorable because of damage to alfalfa from insects. Freezes in Colorado had destroyed the fruit bloom. The relatively poor crop at that date in California was reported as due mostly to light nectar flows from orange and button sage.

The returns from the States that normally produce a fair proportion of their surplus honey crop by July 1 were sufficiently complete to permit of establishing satisfactory estimates except for two States, which are omitted. The reports from Northern and Mountain States which usually produce little surplus by July 1 were not as numerous, and the averages drawn from these are therefore not considered altogether dependable. It has been necessary to omit a number of such States for lack of information. The influence of these upon the United States averages is fortunately not large.

The average yield of surplus honey per colony up to July 1, 1915, for the States reporting is estimated at 18.3 pounds against 20.7 pounds last year. (Columns 11, *a*, and 11, *b*.)

Last year the proportion of the total surplus produced by July 1 was approximately 65 per cent, the early flow being favorable and that later in the summer poor. This year the proportion is 50.6 per cent, the summer bloom having been abundant throughout most of the Northern, Central, and Eastern States. Notwithstanding the season's abundant bloom, the large proportion of rainy and cool days, by suppressing the secretion of nectar, washing nectar from the bloom, and most of all by keeping bees confined to the hive, has resulted in merely a fair crop instead of a heavy one.

The estimate of the usual production by July 1 is 51.9 per cent. These estimates on the proportion of honey usually produced by July 1 (11, *c*) are of much interest, indicating the degree to which the July 1 report may be accepted by producers and others interested in forming a judgment of probable supplies and prices. It appears that, speaking generally, from two-thirds to three-fourths of the surplus is ordinarily produced by that date in the Southern States, including Maryland, Tennessee, and Arkansas, under one-fourth in the extreme Northern and Mountain States, and 40 to 50 per cent in most of the remainder. The usual average for the entire United States is estimated by correspondents to be slightly over half the

year's total. After a few years it will be possible to substitute for these estimates figures based upon the records now being built up.

The average yield for the United States of surplus honey per colony in 1915 according to the September 1 estimate (11, *d*) is 36.2 pounds as against 32.2 pounds in 1914 (11, *e*), an increase over last year of approximately 12 per cent, and a decrease of 11 per cent under the yield of 40.6 pounds in 1913.

These estimates of yield per colony are believed to be somewhat high for the average producer. They are based primarily upon reports from a special list of reporters who are in the main progressive beekeepers, utilizing modern equipment, and obtaining thereby larger yields than the average person who keeps bees. While they are asked to report for the community whenever possible, the reports are often limited to or influenced by the results in their own apiaries. While these averages are checked and modified by returns from the regular crop reports, the figures shown, though below the average for commercial apiaries, are likely above the average for all beekeepers. In any event, the figures on relative number of colonies and yields per colony for 1915, 1914, and 1913 are reasonably comparable, having been furnished by the same reporters, and represent at least the relative production of the three years, as estimated September 1, 1915.

In May, 1914, the correspondents of the bureau estimated the number of colonies to be 103.7 per cent of 1913, while this year the number is shown as 99.8 per cent of 1914. The total production this year, so far as could be estimated on September 1, will be 112 per cent of 1914 and 92.3 per cent of 1913.

The total absolute production of surplus honey in 1915 can not be satisfactorily estimated because of the lack of dependable knowledge of the actual number of colonies.

It is estimated that of the total production, California furnished this year about 12 per cent, Texas 8 per cent, and Iowa and New York 6 per cent each.

The form of honey produced (Table 4, 12) shows that this year, in comparison with last, a slightly less proportion of comb and extracted honey and a slightly greater proportion of bulk comb honey has been obtained.

The Northern States generally, with the exception of Illinois, Wisconsin, and Nebraska, show a high proportion (one-half to two-thirds) of their production in the form of comb honey in sections, while in the South and West generally this form is only from one-third to one-half of all, and in a few States very much less. Conversely, the proportion of bulk comb or chunk honey is relatively high in the Southern States and of extracted in the Western, the latter form comprising 90

per cent of the total crop in Arizona, 85 per cent in Utah and New Mexico, and 82 per cent in California.

The reports on disposition of honey (Table 4, 13) indicate that while for the entire United States 60.8 per cent of the honey removed from the hive is consumed locally, more than one-half is shipped out of the locality where produced in the States of Vermont, New York, Florida, Kentucky, Louisiana, Texas, Wyoming, Colorado, New Mexico, Arizona, Utah, Idaho, and California. Of the 39.2 per cent thus entering this year the main trade channels as a distinctly commercial crop, California furnished about one-fourth, mostly extracted, and Texas one-eighth, practically all extracted or bulk comb honey.

The losses shown to colonies during the season from diseases (Table 4, 14) averages 1.5 per cent for the United States, being most severe in the States of New Jersey, Pennsylvania, Nebraska, Utah, Idaho, and California. The principal bee diseases mentioned were American foulbrood and European foulbrood.

The strength of colonies on September 1 compared with normal strength on that date (Table 4, 15) averaged 97.3 per cent for the United States, being above normal in many of the Northern States. The long drawn out, even if intermittent, flow of nectar over much of the country, while not resulting in a heavy honey crop, has encouraged an unusual amount of brood rearing during the summer, so that colonies are stronger than usual in those sections.

Information reaching the bureau on mid-September indicates that the fall flow is proving very abundant throughout the Middle West and under these conditions, which are believed to obtain also in most of the country east of the Alleghenies, bees in the territory indicated are rapidly accumulating a comfortable supply of winter stores. In many sections they are storing considerable surplus.

IMPORTS AND EXPORTS OF HONEY.

As a result, unquestionably, of the interference of the European war with the exports to that continent of honey from Mexico and the West Indies, much more than the usual supply from the countries to the south has been forced upon the United States markets since the war began.

The total foreign imports into this country for the five fiscal years ending June 30, 1910 to 1914, inclusive, were 104, 113, 115, 116, and 75 thousands of gallons, respectively, of which normally about 45,000 gallons came from Mexico, about 50,000 from Cuba, and 5,000 from Haiti. The import duty on this honey from Cuba is 8 cents per gallon, and from other foreign countries 10 cents. For the first three months of the fiscal year 1915, beginning July 1, 1914, the imports were 53,000 gallons, during the next quarter, ending December 31, they were 85,000 gallons. For the entire fiscal year they amounted

to 303,965 gallons, about three times the quantity imported from foreign countries in any previous entire year, having a stated value of approximately $124,843. Of the total imports for the year, 92,876 gallons came from Mexico, 164,042 from Cuba, 7,309 from Haiti, and 33,571 from Santo Domingo.

In addition to the imports mentioned, this country also received honey from the island possessions, that from Porto Rico and Hawaii this year exceeding slightly in value and probably also in quantity the imports just mentioned from foreign countries. Hawaii ordinarily furnishes shipments to the value of $35,000; the imports this year totaled $35,536. Porto Rico, by reason of the rapid development of this industry in that island, increased its shipments from the value of $8,018 in 1910 to $17,904 in 1911, $42,000 in 1912, $60,000 in 1913, $91,000 in 1914, and for the present year to $94,895.

Practically all of this honey is extracted, and that most of it is of the low grades, used by bakers and not for table use, is indicated by the price of the foreign imports, which averaged during the five years ending June 30, 1914, between 50 and 60 cents per gallon. The pressure of the heavy supply on the markets lowered the import price of foreign honey to 41 cents per gallon before December of last year, and the average import price for the fiscal year just closed is about 41.1 cents.

The total honey crop of the continental United States in 1909 was reported by the census to be about 55,000,000 pounds; expressed in terms of gallons, roughly 5,000,000. This represents production on farms alone and is an admittedly low estimate even for the farm production, as only a little over half of the farms showing bees gave a report on honey production. It is impossible to know what proportion of these farms failed to report honey production because no honey was actually obtained from the bees, and what because of oversight, indifference, or lack of information. No record appears to have been taken of the large production by beekeepers not farmers.

Compared with the total production of the United States as reported by the census, the heavy imports for the present fiscal year, which from all sources probably total over 600,000 gallons, are therefore about 12 per cent, though probably considerably less, if compared with the actual production. Compared with the portion of the home crop actually marketed, however, the percentage would be much larger, and its absolute bulk compared to the quantity of low-grade extracted honey produced here for market is so great that it has seriously interfered with the marketing of the latter and, combined with the financial depression in the South, where the lower grades are largely produced and consumed, has forced the prices of such grades to extremely low figures. The heavy inward movement of foreign

honey shows no present signs of abatement and must be accepted as a probable factor for some time to come.

The quantities of honey exported are not stated in the official returns of exports, but the values of total exports of this commodity for the fiscal years 1910 to 1914, inclusive, were 159, 82, 213, 182, and 136 thousands of dollars, respectively. About two-thirds of this honey is ordinarily shipped from the Pacific coast, 10 to 20 per cent from Porto Rico and Hawaii, and most of the remainder from the port of New York. Evidently, from its source, it is mostly extracted. The exports have been principally to Germany, which has taken from 40 to 60 per cent annually. Canada has taken from 15 to 20 per cent. The exports to the United Kingdom amounted to $59,000 in 1910, but had fallen to $4,000 in 1914. The exports for the present fiscal year, beginning July 1, 1914, just prior to the opening of the European war, amounted to approximately $114,000, the exports to Germany being $10,200, to Denmark $14,375, to the United Kingdom $53,763, and to Canada $14,930. The exports are therefore seen to have suffered some reduction from past years as a result of the war.

The effect of both these movements—increased imports and decreased exports—is to increase the amount of honey that must be disposed of in our home markets. It will be observed that this commerce is concerned in but very slight measure with comb honey, for good grades of which the home market furnishes sufficient demand.

TABLE 1.—*Fall condition of honey bees, 1914; winter confinement, food supplies, and extra protection given during winter 1914–15.*

State.	1 Condition of colonies at beginning of last winter (fall 1914).	2 Usual length of time between fall and spring nectar flows.	3 Longest period confined to hives in usual winter without a flight.	4 Honey needed to winter a colony outdoors.	5 Honey on hand per colony at beginning of last winter.	6 Extra winter protection furnished colonies.						
						Cellars. (*a*)	Double-walled and packed hives. (*b*)	Packed and in cellar (*a* and *b* not separated). (*c*)	Packed, super. (*d*)	Wrappings of tar paper, etc. (*e*)	Straw covering and miscellaneous. (*f*)	Total per cent given winter protection. (*g*)
	P. ct.	*Mos.*	*Mos.*	*Lbs.*	*Lbs.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Maine	100											
New Hampshire	100											
Vermont	89	7.6	3.6	29	25	67	14				14	95
Massachusetts	98	6.2	1.9	29	34	17	39	20				76
Connecticut	105	6.1	1.7	35	28	6		46				50
New York	85	7.2	2.8	31	29	25	33	22				80
New Jersey	99	5.7	2.0	25	27		30					30
Pennsylvania	94	7.0	2.2	31	30	1	35	4	15	3	2	60
Maryland	90	6.0	1.3	30	30	1	9		10	5		25
Virginia	95	5.7	1.3	28	32				3		1	4
West Virginia	90	7.0		35	35		10					10
North Carolina	90	4.6	1.2	26	25		5					5
South Carolina	101	5.2	1.0	30	31		2					2
Georgia	97	4.8	1.0	27	29						1	1
Florida	97	4.2	.5	40	40							0
Ohio	92	6.3	2.0	29	33	10	26		3	6		45
Indiana	94	6.4	2.0	31	34	3	30		4	3		40
Illinois	89	6.8	2.5	32	30	20	26		2		2	50
Michigan	96	7.0	3.2	29	29	30	13	34			3	80
Wisconsin	100	7.0	3.4	31	34	74	16	5		2		97
Minnesota	92	7.6	3.3	36	38	69		30				99
Iowa	86	6.5	2.2	32	28	40	10	21		2	2	75
Missouri	78	6.4	1.6	33	26		5		12		3	20
South Dakota	95	7.0	2.7	37	41	44	1	6			19	70
Nebraska	100	6.4	1.3	32	35	1	30		12		7	50
Kansas	90	5.7	1.6	33	36		1		3	1	5	10
Kentucky	99	5.9	1.4	34	42		2		6			8
Tennessee	96	5.5	1.1	32	36		2			2		4
Alabama	91	5.0	.6	35	36				1			1
Mississippi	100	5.6	.5	29	32							0
Louisiana	92		.5	30	32							0
Texas	104	4.1	.6	34	41				1			1
Oklahoma	81	5.9	1.2	30	25					8		8
Arkansas	85	4.0	.9	35								0
Wyoming	102	8.5	1.4	25	38	26	9			30		65
Colorado	88	7.7	1.2	37	39	1	1		5	4	1	12
New Mexico	104	6.3	.5	36	36		2		2			4
Arizona	100	3.6	.1	33	34							0
Utah	100	8.8	1.4	49	44	1	30		12	7		50
Nevada	100	7.0	1.0	40	35							0
Idaho	95	7.3	3.1	37	39	3	4	20	2	1	25	55
Washington	109	6.4	1.2	37	41		3		1	1		5
Oregon	99	5.0	.7	26	31		7					7
California	103	4.5	.5	33	44							0
United States average	93.6	5.8	1.5	31.9	33.5	9.1	9.0	4.3	2.5	.9	1.0	26.8

TABLE 2.—*Winter losses of honey bees; causes and percentage of colonies lost, winter 1914–15.*

State.	7 Causes and percentages of winter losses.									
	(*a*) Queen lost or impotent.	(*b*) Starvation.	(*c*) Cold, exposure, smothering.	(*d*) Moths and ants.	(*e*) Foul brood and other diseases.	(*f*) Poor honey, dysentery.	(*g*) Late and weak swarms.	(*h*) Lack of young bees.	(*i*) Miscellaneous and unknown.	(*j*) Total loss of colonies.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Vermont	0.1	0.4	0.1	.....	.....	2.7	0.1	.....	7.6	11.0
Massachusetts	.....	.....	2.1	.....	.....	.5	11.1	.....	.....	13.7
Connecticut	.....	16.0	.....	.....	.....	.....	.....	.....	.....	16.0
New York	1.2	.6	.1	.....	.....	9.4	6.4	.....	2.1	19.8
New Jersey	2.2	.....	.....	.....	0.1	.5	1.5	1.3	.5	6.1
Pennsylvania	2.2	1.2	1.7	.....	.....	1.8	2.7	.2	5.9	15.7
Maryland	.3	4.7	.....	0.2	.....	3.7	1.4	1.1	.....	11.4
Virginia	1.5	1.8	.1	.6	.....	1.3	1.4	.4	4.1	11.2
West Virginia	.....	.....	.....	.....	.....	5.7	.....	.....	.....	5.7
North Carolina	.4	2.6	.....	1.7	.....	.....	.4	.....	.....	5.1
South Carolina	5.7	3.3	.....	3.7	.....	.....	.4	.....	.....	13.1
Georgia	2.8	10.7	.....	1.1	.....	.....	.....	.....	.1	14.7
Florida	2.3	.....	.....	.....	.....	.....	2.3	.....	3.8	8.4
Ohio	.8	.....	2.6	.....	1.5	5.4	.2	5.5	.1	16.1
Indiana	.9	1.4	2.2	.....	.6	2.9	.....	1.7	1.1	10.8
Illinois	2.1	.5	2.5	.....	.....	4.3	1.8	.....	.1	11.3
Michigan	2.9	2.6	1.6	.....	.7	2.1	.2	.....	.6	10.7
Wisconsin	4.1	.....	.1	.....	.....	.6	.....	.....	.6	5.4
Minnesota	.2	10.5	.....	.....	.....	5.3	.....	.....	.5	16.5
Iowa	2.4	.1	.....	.....	1.3	3.4	2.7	2.0	1.1	13.0
Missouri	.....	.....	4.3	.....	.....	3.3	.....	.....	23.4	31.0
South Dakota	.4	2.8	3.0	.....	.....	.....	.....	.8	.8	7.8
Nebraska	2.4	3.6	2.6	.....	.....	3.6	.....	.....	3.6	15.8
Kansas	.4	3.5	.1	.....	.....	.....	3.3	.....	.1	7.4
Kentucky	.9	2.7	.7	.1	.2	3.2	.....	.....	1.7	9.5
Tennessee	1.4	3.7	.3	.3	.....	1.0	1.7	.....	.5	8.9
Alabama	.8	10.5	.....	.1	.1	.....	.....	.....	5.8	17.3
Mississippi	.7	11.4	.....	1.3	2.2	.5	.....	.....	7.1	23.2
Louisiana	2.1	5.6	.....	.....	.....	.....	.....	.....	.....	7.7
Texas	1.5	3.1	.....	.2	.2	.....	1.5	.....	.6	7.1
Oklahoma	1.0	1.0	2.4	.....	.....	.3	2.0	.....	8.7	15.4
Arkansas	.....	25.0	.....	.....	.....	.....	.....	.....	.....	25.0
Wyoming	1.7	17.4	.....	.....	.....	.....	.....	.....	.....	19.1
Colorado	2.3	.5	1.4	.....	.6	.8	1.5	1.1	2.3	10.5
New Mexico	1.7	.....	.....	.....	.....	.....	.....	2.5	5.0	9.2
Arizona	1.5	.....	.....	.....	.2	.....	.3	.....	.....	2.0
Utah	4.8	.....	1.0	.....	.1	3.3	.....	1.0	.3	10.5
Nevada	.....	.....	.....	.....	.....	.....	.....	.....	5.0	5.0
Idaho	2.6	.2	.2	.....	.....	.6	.6	1.1	.6	5.9
Washington	.9	.2	16.9	.....	.....	.....	.8	.....	1.0	19.8
Oregon	2.2	.....	.....	.2	1.0	.....	.....	.....	.5	3.9
California	2.5	.1	.....	.....	1.2	.....	.3	.....	.9	5.0
United States, average	1.5	3.2	.9	.3	.3	2.1	1.1	.4	2.8	12.6

TABLE 3.—*Number of colonies (spring count) 1915, condition of bees and honey plants May 1, estimated yield of surplus honey July 1, and indicated yield Sept. 1 for entire season, 1915.*

State.	8	9		10		11					
	Number of colonies, spring count, 1915, compared with previous year.	Condition of colonies compared with normal.		Condition of honey plants compared with normal.		Yield of surplus honey per colony.					
		(a) May 1, 1915.	(b) May 1, 1914.	(a) May 1, 1915.	(b) May 1, 1914.	(a) Reported to July 1, 1915.	(b) Reported to July 1, 1914.	(c) Per cent of total surplus, usually produced by July 1.	(d) For entire season, estimated Sept. 1.		
									1915.	1914.	1913.
	No.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*	*P. ct.*	*Lbs.*	*Lbs.*	*Lbs.*
Maine	100	99	94	99	93	8	8	18	25	30	38
New Hampshire	103	100	91	98	95	18	25	50	28	30	27
Vermont	96	95	95	100	98	5	4	12	40	20	33
Massachusetts	101	96	90	93	91	12	7	47	22	22	31
Rhode Island	100	98	96	90	93	35	10	10	35	40	45
Connecticut	110	98	85	100	90	5	6	17	35	28	35
New York	90	88	95	98	95	13	9	30	45	22	37
New Jersey	98	98	98	97	98	5	8	54	25	12	40
Pennsylvania	96	91	94	94	93	10	15	40	28	28	45
Delaware	98	96	98	94	95	12	18	50	12	20	21
Maryland	102	88	95	91	93	20	32	70	20	25	40
Virginia	106	92	93	87	90	31	32	72	40	35	38
West Virginia	95	93	95	92	94	.....	.....	.....	30	25	20
North Carolina	102	96	92	93	91	21	24	64	28	28	25
South Carolina	101	93	91	92	91	21	21	68	20	18	25
Georgia	100	93	94	92	93	28	30	72	30	30	30
Florida	100	93	97	92	95	48	46	60	45	42	50
Ohio	98	88	100	93	100	5	14	46	20	23	50
Indiana	90	90	96	90	95	7	16	51	24	25	60
Illinois	92	85	98	82	85	6	8	45	25	17	60
Michigan	104	97	98	98	94	13	26	45	45	37	50
Wisconsin	103	98	110	100	93	14	24	40	50	40	60
Minnesota	102	97	98	99	95	12	14	24	50	35	60
Iowa	94	91	100	95	95	16	15	40	45	25	65
Missouri	86	84	85	86	85	18	5	51	33	8	30
North Dakota	105	100	102	100	100	.....	.....	.....	.....	.....	.....
South Dakota	105	93	105	98	98	1	10	9	55	25	50
Nebraska	92	88	95	96	95	6	6	18	40	30	50
Kansas	100	88	86	95	85	6	8	29	30	20	25
Kentucky	102	95	95	91	93	25	8	48	35	25	40
Tennessee	102	92	95	88	92	26	25	67	17	28	30
Alabama	101	91	97	90	95	30	30	85	30	28	35
Mississippi	100	95	93	92	95	25	26	77	33	33	35
Louisiana	96	90	91	90	90	.....	.....	.....	33	35	35
Texas	115	97	115	96	115	17	42	76	40	55	35
Oklahoma	99	89	98	97	96	2	5	33	30	25	35
Arkansas	92	87	92	88	90	15	12	65	20	20	30
Montana	125	97	105	100	100	.....	.....	.....	63	62	35
Wyoming	120	103	108	100	100	.....	.....	.....	70	70	75
Colorado	101	95	110	97	107	1	2	3	29	43	60
New Mexico	115	96	105	103	105	15	7	10	40	55	50
Arizona	110	104	105	110	105	86	59	78	70	60	70
Utah	105	99	105	98	102	8	11	15	50	65	70
Nevada	100	100	100	100	100	.....	.....	.....	65	40	75
Idaho	105	99	115	101	110	0	4	7	63	56	55
Washington	103	100	102	105	100	1	3	19	44	40	45
Oregon	98	99	105	100	100	16	15	45	30	35	40
California	110	100	107	100	120	35	45	52	75	75	36
United States average	99.8	92.7	97.8	93.3	99.1	18.3	20.7	51.9	36.2	32.2	40.6

TABLE 4.—*Form of honey produced, percentage used locally and that sold to outside markets, losses of colonies during season from disease, and strength of colonies on Sept. 1, 1915.*

State.	12 Form of honey produced.						13 Disposition.		14	15
	(a) Comb in sections.		(b) Extracted.		(c) Bulk comb "chunk."		(a) Used locally.	(b) Outside markets.	Colonies lost from disease, 1915.	Strength of colonies Sept. 1, compared with normal.
	1915	1914	1915	1914	1915	1914				
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Maine [1]	80	80	17	15	3	5	75	25	5.0	88
New Hampshire [1]	85	.....	15	.....	0	.....	.....	.....	0	100
Vermont [1]	90	66	8	28	2	6	5	95	2.0	110
Massachusetts [1]	87	67	13	32	0	0.7	94	6	1.0	105
Rhode Island [1]	20	5	80	95	0	0	100	0	1.0	105
Connecticut	61	48	29	47	10	5	83	17	.2	97
New York	61	47	39	50	0	3	45	55	.9	104
New Jersey [1]	77	25	23	75	0	0	96	4	5.0	94
Pennsylvania	60	65	30	29	10	6	75	25	4.0	95
Delaware [1]	60	.....	30	.....	10	.....	.....	.....	0	100
Maryland	85	69	10	22	5	9	80	20	.8	105
Virginia	75	87	13	12	12	1	75	25	2.3	103
West Virginia [1]	.....	57	.....	38	.....	5	.....	.....	.....	.....
North Carolina [1]	34	45	17	30	49	25	51	49	0	101
South Carolina	40	.....	30	.....	30	.....	98	2	.4	98
Georgia [1]	40	28	16	33	44	39	75	25	1.0	94
Florida [1]	55	11	45	88	0	1	42	58	0	80
Ohio	65	66	32	32	3	2	75	25	2.0	95
Indiana	64	52	21	36	15	12	97	3	1.5	100
Illinois [1]	34	42	65	56	1	2	59	41	2.0	96
Michigan	54	56	46	43	0	1	54	46	2.0	96
Wisconsin	43	41	57	58	0	1	58	42	1.5	97
Minnesota [1]	50	36	45	63	5	1	55	45	.1	106
Iowa	58	56	40	42	2	2	65	35	2.0	102
Missouri	34	32	37	38	29	30	95	5	2.4	102
North Dakota [1]	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
South Dakota	62	77	30	22	8	1	85	15	2.0	103
Nebraska [1]	36	43	63	42	1	15	64	36	5.0	100
Kansas [1]	65	67	25	28	10	5	99	1	.1	99
Kentucky	45	49	50	33	5	18	33	67	1.0	98
Tennessee	22	31	28	23	50	46	88	12	0	89
Alabama	32	34	42	41	26	25	55	45	0	95
Mississippi	19	49	41	26	40	25	71	29	1.0	94
Louisiana [1]	10	0	80	100	10	0	35	65	0	100
Texas	1	4	52	51	47	45	35	65	.5	95
Oklahoma [1]	37	36	15	17	48	47	99	1	.3	100
Arkansas [1]	28	25	32	15	40	60	92	8	0	94
Montana [1]	70	.....	27	.....	3	.....	67	33	3.0	95
Wyoming [1]	97	92	3	8	0	0	6	94	.3	100
Colorado	70	67	30	30	0	3	23	77	2.0	89
New Mexico	5	31	85	61	10	8	42	58	1.4	95
Arizona	10	6	90	94	0	0	36	64	1.0	96
Utah [1]	15	17	85	83	0	0	32	68	4.0	95
Nevada [1]	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Idaho [1]	60	47	37	51	3	2	23	77	5.0	101
Washington [1]	32	46	68	54	0	0	54	46	2.0	95
Oregon [1]	48	64	52	34	0	2	92	8	0	90
California	17	18	82	79	1	3	13	87	4.5	97
United States average	40.7	41.7	41.3	42.1	18.1	16.2	60.8	39.2	1.5	97.3

[1] Not enough reports for fully dependable averages.

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ENT. INSECTS

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 329

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER March 6, 1916

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By

ARTHUR W. JOBBINS-POMEROY, Entomological Assistant

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INTRODUCTION.

Certain species of the insects known as "buffalo gnats" are important enemies of man and domestic animals in the United States as well as in other countries. Although the principal area of abundance in North America is in Canada and the Northern States, outbreaks of pests of this group occur as far south as Louisiana and Florida. While they are dependent upon running water for development, they make use of very small streams and, to some extent, of irrigation ditches, and are consequently found occasionally in considerable numbers in the drier parts of the country.

About 20 years ago buffalo gnats attracted great attention along the lower Mississippi River. They frequently became so abundant that plantation operations were stopped on account of very painful attacks against live stock as well as human beings. These great outbreaks were due to conditions established by the overflow of the Mississippi River. The perfection of the levee system has changed these conditions so that the outbreaks are less frequent and of greatly reduced severity. Nevertheless, these insects are still abundant enough to be considered a pest in the Mississippi Valley as well as in many other portions of the South.

The damage done by buffalo gnats results from their painful bites and the loss of blood which ensues. When they are abundant they

[1] Resigned Nov. 20, 1914.

NOTE.—This paper is of interest to persons living east of the Mississippi River.

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sometimes cause the death of live stock. At the present time no cases of disease transmission can be attributed definitely to buffalo gnats, but there is a possibility that future investigations will show some important connection with the transmission of diseases.

All of these considerations make it advisable to place on record a considerable number of observations which will serve as a basis for the control of these insects wherever they occur.

The major part of the biological experiments outlined in this paper were carried on at Spartanburg, S. C. The author wishes to express his thanks to Mr. A. H. Jennings, under whose direction the work was done, to the Thompson-McFadden Pellagra Commission for many courtesies received, and to the directors of the Spartanburg Hospital for the generous way in which they afforded laboratory accommodations and facilities.

THE ADULT STAGE.

DESCRIPTION OF EXTERNAL ANATOMY.

The adults of the genus Simulium are usually very small, the largest known North American species (*S. pictipes*) not measuring more than 4 mm. in length. They are compact in shape, the head being decidedly small in proportion to the rest of the body, and the thorax greatly developed and curiously humped. In some species the thorax and abdomen are very pubescent, in others almost naked. In color the different species vary greatly, ranging from brilliant iridescent yellow and various shades of gray to almost black.

The species of Simulium are holoptic in the male and dichoptic in the female. In the female the facets of the eyes have an equal gradation in size, diminishing somewhat toward the margin. In the male the facets suddenly decrease in size along a line extending on each side from the antennal socket around to the post-genæ, giving the lower portion of the eye the appearance of being divided off by a suture. In color the eyes are usually iridescent bronze in the female and deep iridescent red in the male. Ocelli are wanting in both sexes.

The antennæ are short, moniliform, and 11-segmented. In the species here dealt with the antennæ of the female have the first segment short and cup-shaped. The second is longer, the apical end bearing a chitinous ring which serves as the point of attachment for the third segment, which is nearly the same in length as the second, but pedicellate. The remaining segments are nonpedicellate, broadly joined. Segments 4, 5, 6, 7, 8, and 9 are subequal. The tenth segment is slightly longer. The eleventh is the longest of the entire antenna, narrows to a point at the apical end, and bears from two to three short, strong bristles. The first two segments are minutely pubescent, with a few strong bristles on the apical portion; the re-

maining segments are densely covered with minute pubescence interspersed thickly with stronger hairs. The antennæ of the male are similar in structure to those of the female, except that they are more slender and have the third segment much longer, twice the length of any of the succeeding segments, and the tenth segment usually the same length as the one immediately preceding it. (Figs. 1 and 2.)

FIG. 1.—*Simulium venustum.* Antenna of adult female. Greatly enlarged. (Original.)

The mouth parts are modified in both sexes into a piercing beak, somewhat similar to that of the Tabanidæ. In the male the organs have become greatly reduced both in strength and armature, so that they are apparently unable to pierce the skin of vertebrates.

DESCRIPTIONS OF INTERNAL ANATOMY.

DIGESTIVE SYSTEM.

Pl. I, fig. 2.

The following is a description of the digestive organs of *Simulium venustum.* The diverticulum of the oesophagus, or sucking stomach (*v e*), which is sometimes described as the midintestine or stomach, and whose function seems to be primarily that of a reservoir for blood, is a large membranous bag capable of great distention. At its caudal end it narrows to the constriction known as the pyloric valve (*jp*). This is the place of attachment of the Malpighian tubes.

FIG. 2.—*Simulium venustum.* Antenna of adult male. Greatly enlarged. (Original.)

The Malpighian tubes (*m*, *m*), which are greatly developed in this insect, are four in number and are constricted at intervals, with corresponding lobular enlargements. They extend from the base of the diverticulum to its cephalic end, turning again caudad, and ending, as far as can be ascertained, in a small blind nodule. They are opaque white in specimens which have not fed, or specimens dissected on emergence, but show remarkable changes in color at various periods after engorgement. Sometimes they are pink, sometimes rather brownish, and in specimens which have engorged and lived for 40 hours they become checkered brown with transparent intervals.

The ileum (*i*), which is situated immediately below the pyloric valve, is an elongate, rounded intestine, somewhat curved when in its natural position. The substance which it contains is invariably more solid than that found in the diverticulum, large granules being frequently present.

Toward its caudal end the ileum narrows into what is probably the colon (*c*), which leads in turn directly into the sacklike rectum. This is round in shape, transparent, deeply striated, and capable of great contraction and distention. It contains six large oval glands (*rg*), which are somewhat similar to the rectal glands of *Stomoxys calcitrans* L. At its caudal end the rectum contracts into the external orifice, or anus (*a*).

Female Reproductive Organs.

Pl. I.

The following is a description of the reproductive organs of the female of *Simulium venustum*. The two ovaries (*lo*, *ro*) are situated laterad of the ileum (*i*). They are small pear-shaped organs, transparent and composed of a thin outer membrane which forms a sack. The interior is filled in newly emerged adults with many small nuclear eggs. (Pl. I, fig. 1.) Joining the ovaries to the diverticulum and the basal membrane of the outer skeleton of the abdomen are large tracheæ, which branch many times, finally ending in thin threads. The caudal end of each ovary narrows into a tubular oviduct (*od*). The two oviducts join and form the cephalic end of the tubelike structure known as the utero-vagina (*v*). The utero-vagina and oviducts lie immediately above the lower end of the rectum. Leading from the cephalic end of the utero-vagina on the right side is a very narrow tube which terminates in a round, bulb-like structure, black in color, with a transparent membrane. This is the spermathecum (*s*), whose function is that of a reservoir for the spermatozoa injected by the male at the time of copulation. When an egg is deposited fertilization is effected as the egg passes the orifice in the spermathecum.

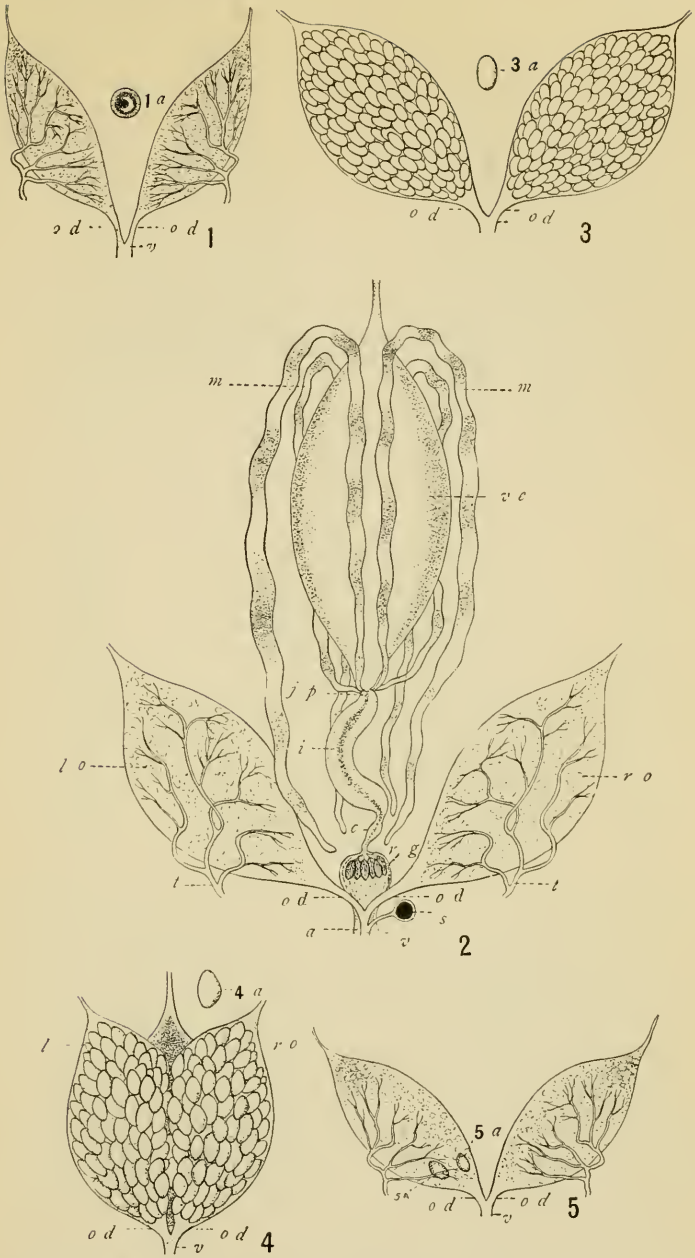
Development of the Eggs.

The stages in the development of the eggs within the ovaries may be described at five different stages, as follows:

First stage.—The eggs are round, very small, rather transparent, and are present in the ovary in large numbers. As a rule they are rather indistinct. (Pl. I, fig. 1.)

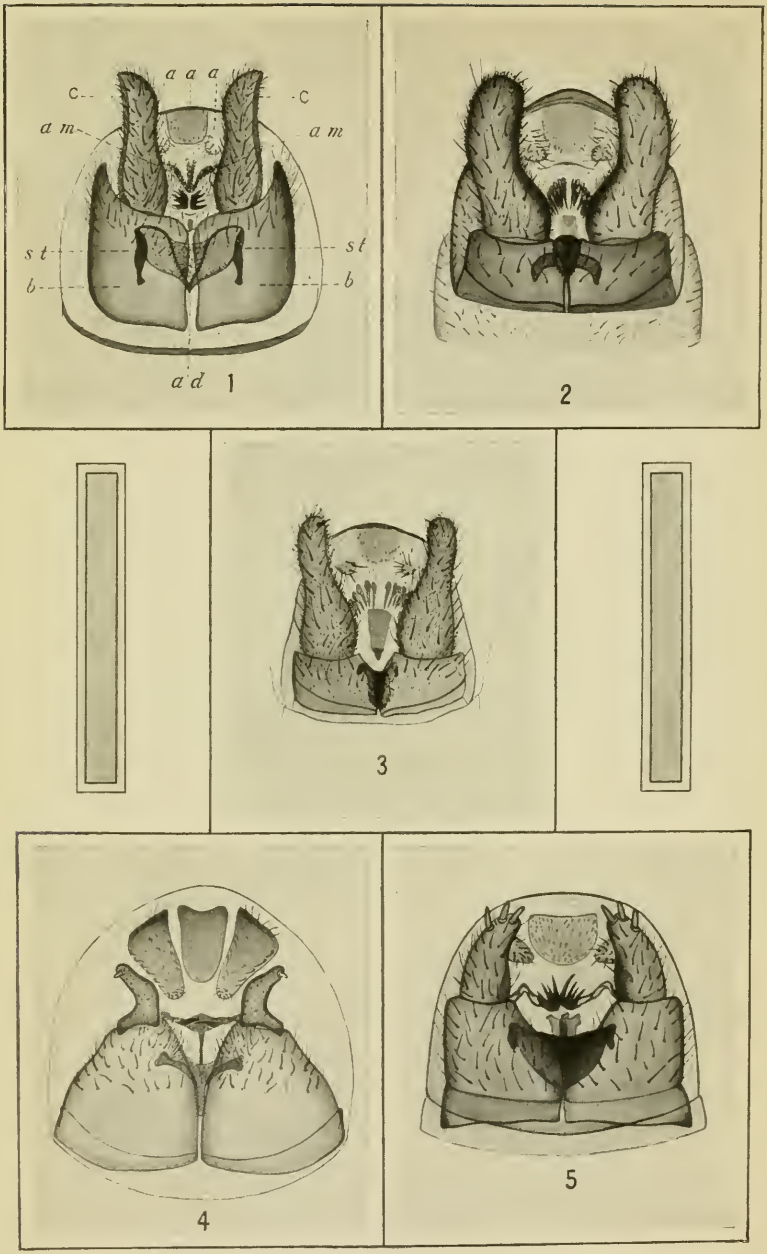
Second stage.—The eggs become denser and generally larger toward the oviduct, more irregular in shape with a tendency toward an oval form. As a rule they are still somewhat indistinct. (Pl. I, fig. 2.)

Third stage.—The eggs are of a perfect oval shape, dense as a rule, and of nearly equal development, those near the oviduct possibly larger. These latter have a tendency toward a slight bulge on one side. The shell has become somewhat denser in appearance, and the eggs on the whole are very distinct. (Pl. I, fig. 3.)



DEVELOPMENT OF EGGS WITHIN THE OVARIES OF SIMULIUM VENUSTUM AFTER A BLOOD MEAL.

FIG. 1.—Condition of ovaries corresponding to stage 1 (without feeding); 1*a*, single egg from same, larger scale. FIG. 2.—Condition of ovaries corresponding to stage 2 (after blood meal); also internal anatomy of abdomen; *ve*, ventriculus or stomach; *m*, *m*, Malpighian tubes; *jp*, juncture of Malpighian tubes and location of pyloric valve; *i*, ileum; *c*, colon; *rg*, rectal glands; *od*, *od*, oviducts; *a*, anus; *v*, vagina; *s*, spermathecum; *lo*, left ovary; *ro*, right ovary; *t*, *t*, tracheæ. FIG. 3.—Condition of ovaries corresponding to stage 3 (after blood meal); 3*a*, single egg from same, larger scale. FIG. 4.—Condition of ovaries corresponding to stage 4 (after blood meal); 4*a*, single egg from same, larger scale. FIG. 5.—Condition of ovaries after oviposition; 5*a*, large, fully developed eggs left near oviducts; remainder of ovary corresponding to stage 1. Highly magnified. (Original.)



MALE GENITALIA OF SIMULIUM.

FIG. 1.—Genitalia of male *Simulium pictipes*: *c*, *c*, Claspers; *a*, *a*, *a*, anal plates; *am*, *am*, arms; *b*, *b*, basal pieces; *st*, *st*, styli; *ad*, adminiculum. FIG. 2.—Genitalia of male *Simulium venustum*. FIG. 3.—Genitalia of male *Simulium jenningsi*. FIG. 4.—Genitalia of male *Simulium bracteatum*. FIG. 5.—Genitalia of male *Simulium vittatum*. All greatly enlarged. (Original.)

Fourth stage.—The eggs are fully as large as those newly laid on grass blades, of the same triangular form, very dense, the shell very strong, and not differing from eggs just laid, with the exception that occasionally they may be slightly smaller. (Pl. I, fig. 4.)

Fifth stage.—One or two large eggs are usually left in the ovaries near the oviduct, and the rest of the ovary is entirely filled with the typical round eggs of the first stage. This stage is found after adults have finished ovipositing, and also in specimens taken actually engorging, concerning which more will be said later. (Pl. I, fig. 5.)

The Genitalia of the Male.

Pl. II, figs. 1–5.

The structure of the genitalia of the male shows remarkably constant specific characters. Their systematic value may be seen from the striking differences in the illustration. The determination of the species based on color alone is at best unsatisfactory owing to the amount of variation in individuals of the same species and fading of color in dry mounted specimens. The appearance of the structure of the genitalia does not change when the specimens are preserved in alcohol, and in dried specimens the original shape can be completely restored by the following method:

The last segment of the abdomen of the male after being removed with sharp scalpel or needle is placed in 6 per cent potassium hydroxid (KOH) and left until the soft parts are removed, the chitinous portions remaining intact. The material is then washed with water, run through alcohol in the usual way up to 100 per cent, transferred to xylol, and mounted in balsam, so as to give a direct caudal view as shown in Plate II, figures 1–5. Some of the European species have been studied in regard to the genitalia of the males by Lündstrom, but nothing has been done so far on American species.

The segments to which the organs of the genital armature are attached are collectively designated under the name hypopygium. The most prominent organs of the hypopygium are the two claspers (*c c*) and the basal pieces to which they are attached. The claspers may be either large, fingerlike, as in *S. venustum*, or greatly reduced and somewhat hook shaped as in *S. bracteatum*. They sometimes bear a spine at the distal end as in *S. venustum*, a single chitinous fingerlike process as in *S. bracteatum*, or three or four such processes as in *S. vittatum*. The basal pieces (*b*, *b*) to which the claspers are articulated are divided by a suture near the base. They are very large in *S. bracteatum* and are reduced in *S. venustum*. The relation between the size of the claspers and basal pieces seems to be very

constant. If the claspers are large the basal portion is much smaller in proportion, and vice versa.

There are three chitinous plates (*a*, *a*, *a*,) which are situated toward the dorsal surface of the hypopygium and surround the anal orifice. The two lateral plates are generally armed with spines or stout hairs.

Ventrad of the plates and extending laterad on each side are two narrow chitinous flanges (*am*, *am*) bearing mesally groups of strong spines, sometimes in a large number as in *S. venustum* and sometimes reduced to only two as in *S. bracteatum*. These structures have been termed by Lündstrom the "arms." Ventrad of these spines and not easily distinguishable, extending inwardly, is a long, weak, chitinous piece, apparently the sheath of the penis. Ventrad and in front of this piece is a triangular troughlike sclerite called the adminiculum (*ad*), which is attached to two strong chitinous arms (*st*, *st*), termed by Lündstrom the stylus.

HABITS OF THE ADULTS.

Copulation.

The writer has found adults in copula flying near the stream from which they were emerging, but they at once separated on being disturbed. Dr. Sambon informed the writer that in Italy he has found the males resting on the reeds in swarms, apparently waiting for the females to emerge.

Dispersion.

It has been stated by several writers that the females travel long distances in search of food, but whether they are prompted by a desire for blood or are involuntarily carried away by the wind is a matter difficult to determine.

The writer has been severely bitten by the females of *S. johannseni* Malloch and *S. forbesi* Malloch in the sand-dune region of Havana, Ill., at a distance of 5 and even 6 miles from the only possible breeding place, which was the Illinois River. The fact that the adults crossed a bare and sandy waste with little or no wind, and that no males were present, seems to indicate that their flight was voluntary. Riley says that they may be carried 30 or 40 miles. They are sometimes attracted to light, as the writer has found a few specimens flying around a lamp at night.

Feeding Habits.

The adult female flies of all the species discussed in this paper, with the single exception of *S. pictipes*,[1] have been frequently observed feeding on the blood of mammals and, so far as the writer

[1] One female of this species, fully engorged with blood, was taken from a mule's ear by Mr. A. H. Jennings at Spartanburg, S. C., in 1912.

has observed, are limited to this diet. There are only two definite records to the writer's knowledge of Simulium feeding upon anything other than the blood of mammals. One is by Hagen (1883), who states that he found Simulium attacking and feeding upon the chrysalids of a butterfly (*Pieris*) *Neophasia menapia* Felder. He does not, however, state the exact species which he found so doing, and remarks that it was similar to the New England "black fly." The other record is by H. Pryer,[1] who states that in Japan he found Simulium attacking the larva of a sphingid, *Smerinthus planus* Walk., and also the imago of *Stauropus persimitis* Butl.

A detailed study was made by the writer in the region of Spartanburg, S. C., of the feeding habits of *Simulium venustum*, which was found from early spring to late fall engorging within the ears of horses and mules. Though invariably present on these animals, they were seldom found on cattle or on man. The severity of the attacks of this species depend both upon the time of year and the time of day. It is generally believed that the worst attacks occur in early spring and in early fall, and the writer found adults more numerous during the first three weeks of September than they had been since the middle of June. They appear to be most active from 3 p. m. to almost dusk. They are rather easily disturbed while feeding, and unless much distended will struggle violently to disengage themselves from the long hairs in the interior of the mules' ears. It has been noticed repeatedly that even the well-engorged specimens will retract their beaks and successfully fly away and not fall to the ground and crawl away to die, as has heretofore been claimed by certain writers. The fact that they are so easily disturbed and bite only under certain conditions probably accounts for the failure thus far of all efforts to get them to engorge while in captivity. While confined on the human body in a vial they make frantic efforts to escape and after 20 minutes become so exhausted as finally to remain on their backs with scarcely a sign of life. Whether the vial was covered to exclude the light or not, these experiments were unsuccessful at any time of day, both with reared specimens and captured ones. When placed in jars containing cloth saturated with defibrinated cow's blood a few took a small amount of blood into the crop, but there was no distension of the abdomen.

Oviposition.

In the method of oviposition the different species of Simulium, whose life history has been studied in detail, show characteristic adaptations according to their habitat, and may be classified arbitrarily into two distinct groups. Although this grouping applies clearly to conditions in South Carolina, it is possible that exceptions may be found in other regions.

[1] See Bibliography, p. 35.

GROUP 1.

Group 1 contains species normally restricted to rivers which have rocky beds and such obstructions as bridge piles, piers, and, in time of floods, partly submerged trees. These species deposit their eggs at the level of the water, or just below, on any convenient surface, such as the bare portions of rocks, sunken posts, and collections of water-worn débris, always where the current is exceedingly swift. Eggs have never been found by the writer on any surface that was not smooth or that was at all covered by moss, algæ, or other aquatic growths. Of the five species whose methods of oviposition are discussed in this article, *S. pictipes* alone belongs in this group. The oviposition and early life history of this species were first described by Dr. W. S. Barnard in the American Entomologist in 1880. He states that the eggs are long ovoid in form, and gives a figure showing them deposited in a vertical position. He also states that the young larvæ were issuing from the eggs deposited on the rocks above the water line and were passing down into the water to begin aquatic life. If this was the case, the eggs must have been moistened continually by the spray and not left in a dry state, as is implied, the reason for which surmise will be discussed at length farther on.

The eggs of this species which were found by the writer seemed to have been deposited indiscriminately in a horizontal as well as in a vertical position. The angles appeared rather broadly rounded. (Pl. III, fig. 6.) Surrounded by a viscous substance known as the matrix, in which they are fairly evenly distributed, they are laid normally in masses on the smooth surface of the rocks just below the level of the water. The matrix is brownish yellow at first, afterwards turning brown. Usually several females will oviposit in the same spot, causing the layers to overlap.

GROUP 2.

Group 2 is made up of species which are peculiar to small streams with less force of current and with only submerged herbage or occasional small collections of sticks and stones to serve as a place for the attachment of the immature stages. As a general rule the situation selected for oviposition is a grass blade bent at right angles and trailing just at the surface of the water and with its surface continuously moistened.

S. vittatum almost invariably oviposits on grass blades in small streams. The eggs adhere to the grass blades by a creamy viscous matrix entirely covering the eggs. This matrix turns yellowish brown on the second day and becomes gradually darker until the eggs hatch. The eggs are laid in a single layer, as a rule, very closely together. Several females often select the same situation and, as in the case of *pictipes*, the layers often overlap one another.

At Dallas, Tex., in March, 1913, *S. vittatum* was found by the writer ovipositing in considerable numbers on the small stones in the limestone bed of a small stream which was almost devoid of submerged herbage. The eggs were laid generally below or at the surface of the water. In a few instances they were found an inch or so above the water, but this was owing to a decrease in the amount of water, which varies considerably in this and the majority of streams in Texas. This species has been found by the writer on one occasion at Havana, Ill., ovipositing in large numbers on the bridge piles in the Illinois River. The eggs were deposited at or just below the level of the water, and as the river was falling at the time at the rate of an inch a day, the eggs underwent complete desiccation, and all were destroyed. The bridge piles were literally covered with the matrix and eggs, and many females, becoming entangled, died adhering to the viscous masses. This oviposition of this species in the main river seems to have been an abnormal occurrence, as the larvæ have never been found in this situation. Another species, however, *S. johannseni*, according to the writer's observations, breeds in enormous numbers in the main channel in the spring, around the submerged vegetation near the banks and wherever there is an obstruction.

S. venustum, in the regions studied, belongs entirely to group 2. The eggs are laid on submerged grass blades and the like in small streams, in situations similar to those selected by *S. vittatum*. The eggs are more evenly arranged than those of that species, the matrix is not smeared so profusely, and the egg mass is generally oblong in shape and very compact. This species has many times been observed ovipositing, and specimens which subsequently laid a full quota of eggs in captivity were taken from the stream as they alighted.

The oviposition in captivity of *S. venustum* was observed by the writer at Spartanburg, S. C., on September 16, 1913. A female *S. venustum* was noticed at 5.08 p. m. moving up and down a small stream within a space of about 4 feet, apparently seeking a suitable place for oviposition. She would touch the water for an instant and then, apparently dissatisfied, fly up again. This peculiar interrupted flight was continued for a period of two minutes, after which she alighted on a grass blade which seemed to be satisfactory. Immediately a bottle was placed over her and she was at once taken to the laboratory. The stream from which the specimen was taken was situated 50 yards from the laboratory, and thus little time was lost in transit. The bottle in which the specimen was taken was partly wet inside. At 5.13 p. m., as soon as the bottle was placed on its side, she felt around for two minutes and then settled into position, rapidly thrust out the end of her abdomen, and deposited an

egg about every two seconds, as fast as she could extend and retract her ovipositor. Ten eggs were laid in a sort of half circle and then the intervening space was filled up until each egg touched another. In addition a few were laid a short distance away and the intervening space filled up. Oviposition continued steadily until 5.20 p. m., when she stopped, turned around, felt the mass with her feet, and commenced again. She stopped at 5.21 for 30 seconds and cleaned the end of her abdomen. Another lot of eggs was then laid a little farther off, in a long, irregular row, about five eggs wide. Oviposition was finally ended at 5.27.30 p. m.

She seemed always to feel for a suitable place before ovipositing. A dry spot was invariably rejected. One hundred and forty-five eggs were laid from 5.15 to 5.20, about 80 eggs from 5.20 to 5.21 (this seemed to be the maximum rate of oviposition), and about 117 from 5.21 to 5.27.30. The total number of eggs laid was 349. As there were two interruptions, one at 5.20 for three seconds and one at 5.21 for 30 seconds, the length of time spent in oviposition was 12 minutes. The average rate at which the eggs were laid, therefore, was about one every two seconds.

The abdomen was dissected, and only one developed egg was found. This was in the oviduct, showing that the oviposition was normal, as all developed eggs, with this exception, had been deposited.

S. bracteatum seems to be entirely restricted to the smaller streams, and its method of oviposition is similar to that of *S. venustum* in all respects. It is of the same size as *venustum* and deposits about the same number of eggs at one oviposition.

S. jenningsi is so closely allied to *S. venustum* that it is extremely difficult to distinguish the egg masses of the two species, the main points of difference being the smaller size of the *S. jenningsi* mass and the somewhat smaller number of eggs that are deposited.

The time of day generally chosen for oviposition by these five species of Simulium is from about 4.30 p. m. to 5.30 p. m., or even until dusk. The weather conditions most favorable seem to be sunshine and lack of wind. Females have been found ovipositing at a maximum water temperature of about 95° F. The earliest records of oviposition were made by the writer at Dallas, Tex. (latitude 32° 4′ 8″), on March 25, and the latest at Spartanburg, S. C. (latitude 34° 50″), on November 2.

There have been various estimates given by authors, both in Europe and America, upon the number of eggs laid by Simulium. The number of eggs stated to have been laid, or probably laid at one oviposition by a single female, varies from 500 to 1,500. This latter figure, given for the European species *S. reptans* L. (*S. columba-*

schense Fab.), is probably erroneous, as the species is very like *S. venustum* in size and structure. It is the opinion of the writer, from many observations, that the largest possible number of eggs which are deposited at one time by a single female can not exceed 500.

The question whether eggs of Simulium can be subjected to desiccation and then hatch after being immersed again in water is of interest, as it has been suggested that in the more or less torrential streams found in Texas and the Western States, which flow only a few months in the year, the eggs might remain in a dry condition during the summer and hatch in the fall or spring with the rising of the water. For this reason experiments have been made by the writer to ascertain whether Simulium eggs, after partial or complete desiccation, would hatch on being again placed in water, as is the case with some species of mosquitoes. These experiments all showed that at Spartanburg, S. C., the contents of freshly laid eggs became completely disintegrated after being thoroughly dried, and that when the eggs contained embryos, the latter became distorted on the second day after removal from the water, and though they were replaced in running water after that period the contents of all finally disintegrated without a single egg hatching.

When eggs are found at any distance above the water line, the writer believes investigation will show that a fall in the water level has occurred. The great outbreaks of Simulium in the large rivers during the early spring are due primarily to the fact that the rising water submerges the growth on the banks and that the water either rises or remains at the same level throughout that period, thus preventing desiccation of the eggs.

THE EGG STAGE.

The eggs of Simulium are usually rather triangular in shape, with the angles broadly rounded. (Pl. III, figs. 1–5.) The egg of *S. pictipes* (Pl. III, fig. 6), however, is more ovoid in shape than that of the four other species dealt with in this paper. The shell, which is very tough and apparently somewhat chitinous, withstands the action of the water for a considerable period without disintegrating, and has been found by the writer in a good state of preservation after six weeks in this element.

The color of the egg when first laid (Pl. III, fig. 1) is opaque white, which changes to yellowish brown as the development of the embryo proceeds. The interior of the newly laid egg appears to be an even mass of yolk substance. When the egg contains a half-developed embryo the yolk substance seems to be consolidated into a central mass, indented at both extremities and surrounded by layers of

closely arranged cells (Pl. III, fig. 2). The interior of an egg containing an embryo three-fourths developed has a peculiar banded appearance (Pl. III, figs. 3, 4), but as the time of hatching approaches the most noticeable features are the cephalic eye spots on the embryonic larva, which become more and more distinct. (Pl. III, fig. 5.) Detailed studies on the embryology of Simulium have been made by Mecznikow,[1] Kölliker,[1] and Graber.[1]

The average period of incubation, from June to October, of the species studied by the writer at Spartanburg, S. C., was about 8.8 days; the minimum period, 7 days; and the maxium, 12 days. The following table will show the normal variation in that region from June to October:

Table showing period of incubation of eggs of Simulium.[a]

Lot No.	Species.	Date of oviposition.	Number of days of incubation.												
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	S. venustum	June 12	a	a	a	b	b	c	c	d	d	h	h	....	....	....
2	S. vittatum	June 21	a	a	a	b	c	c	c	d	h	....	....	....	....	....
3	.....do	July 29	a	a	a	b	b	c	c	c	d	h	h	h	h	....
4	S. bracteatum	Sept. 6	a	a	b	b	c	c	d	h	....	....	....	....	....	....
5	.....do	Sept. 11	a	a	a	a	b	b	b	c	c	c	d	h	....	....
6	S. venustum	Sept. 16	a	b	b	c	c	d	h	....	....	....	....	....	....	....
7	.....do	....do	a	a	b	b	c	c	d	h	....	....	....	....	....	....
8	.....do	....do	a	b	b	c	c	d	h	....	....	....	....	....	....	....
9	.....do	....do	a	b	b	c	c	d	h	....	....	....	....	....	....	....
10	.....do	....do	a	b	b	c	c	d	h	....	....	....	....	....	....	....
11	.....do	....do	a	b	b	c	c	d	h	....	....	....	....	....	....	....
12	.....do	....do	a	a	b	b	c	c	d	h	....	....	....	....	....	....
13	.....do	....do	a	b	c	c	d	d	h	h	h	....	....	....	....	....
14	.....do	....do	a	b	c	c	d	d	h	h	h	h	....	....	....	....
15	.....do	....do	a	a	b	c	c	d	d	h	h	h	h	....	....	....

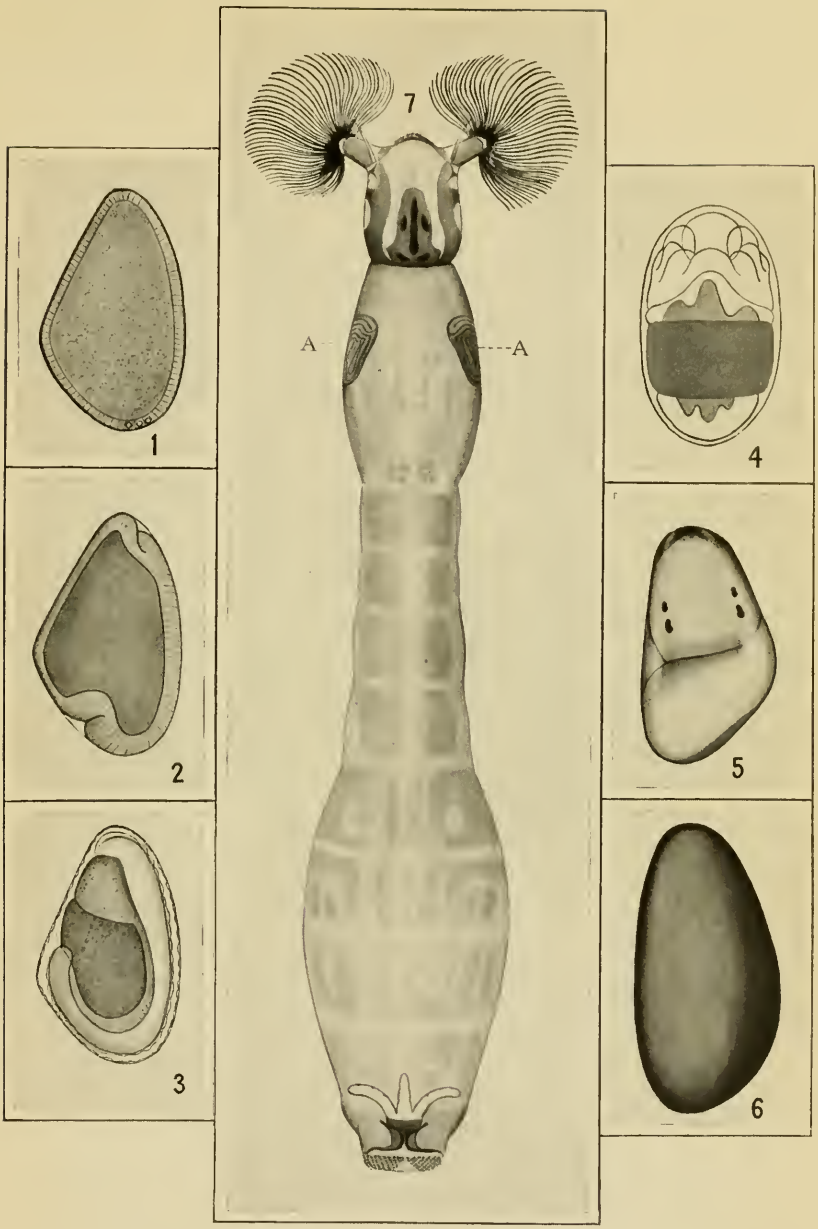
[a] Letters indicate stage of incubation, shown on Plate I, as follows: a, corresponds to fig. 1; b, corresponds to fig. 2; c, corresponds to figs. 3, 4; d, corresponds to fig. 5; h, date of hatching.

The eggs seem to hatch equally well in either still or running water. The percentage of eggs that hatch is very high when they are placed so that the water reaches them, the average sterility of a series of lots kept under observation in normal conditions being from 4 to 5 per cent. The approximate percentage of egg masses, however, that is deposited under such favorable conditions is certainly relatively small as compared with the total number deposited, and the location of the egg mass seems to be the dominant factor in determining the successful hatching of the larva and the consequent abundance of the insect.

THE LARVAL STAGE.

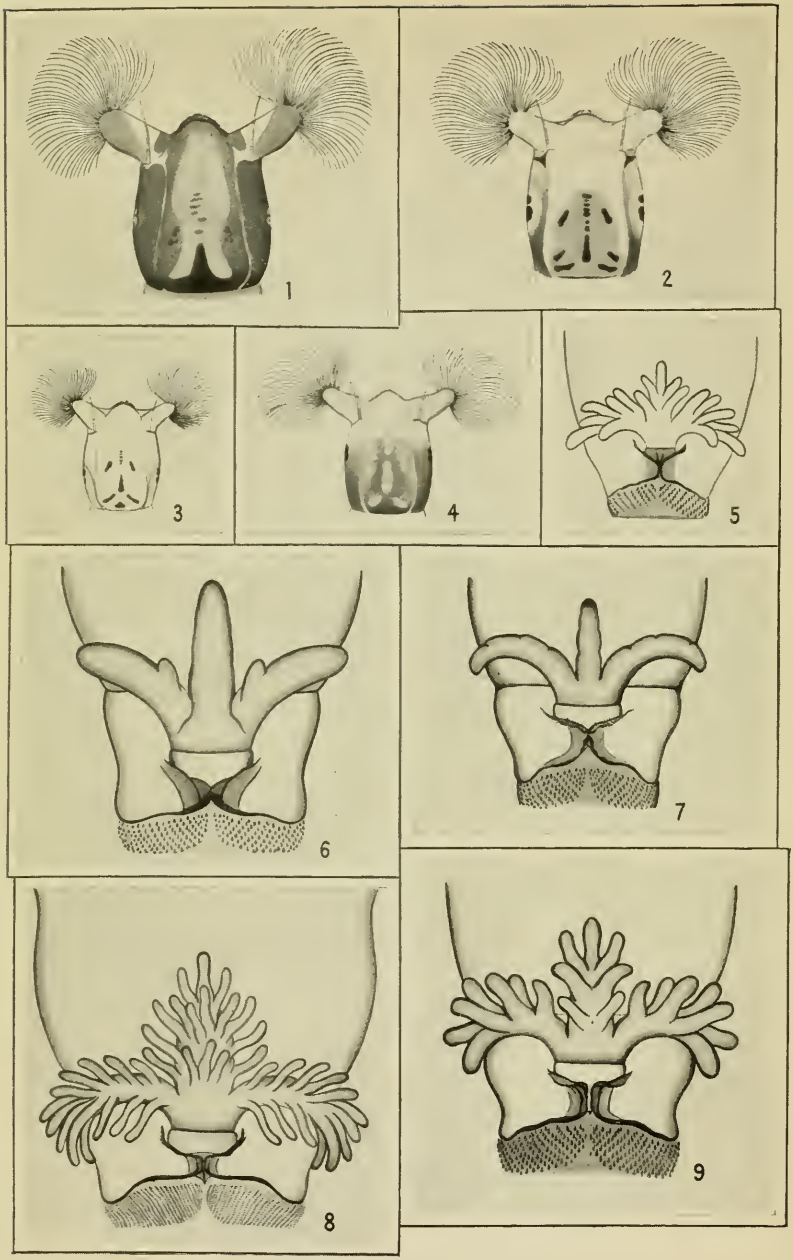
The larvæ of the known species of Simulium, as will be discussed at length farther on, are invariably aquatic in their habits and re-

[1] See Bibliography, p. 35.



EGGS AND LARVA OF SIMULIUM.

FIG. 1.—Egg of *Simulium venustum*, freshly laid. (After Meeznicow.) FIG. 2.—Egg of *Simulium venustum*, second to fourth day. (After Meeznicow.) FIG. 3.—Egg of *Simulium venustum*, fourth to sixth day, showing "banded appearance." (After Meeznicow.) FIG. 4.—Same, dorsal view. (After Kölliker.) FIG. 5.—Egg of *Simulium venustum*, just before hatching, showing larva in a free condition within the shell. (Original.) FIG. 6.—Egg of *Simulium pictipes*. (Original.) FIG. 7.—Larva of *Simulium bracteatum*, showing histoblasts of pupal filaments, A, A. All greatly enlarged. (Original.)



HEADS AND RECTAL GILLS OF SIMULIUM LARVÆ.

FIG. 1.—Head of larva of *Simulium pictipes*. FIG. 2.—Head of larva of *Simulium vittatum*. FIG. 3.—Head of larva of *Simulium jenningsi*. FIG. 4.—Head of larva of *Simulium venustum*. FIG. 5.—Rectal gills of larva of *Simulium jenningsi*, typical form. FIG. 6.—Rectal gills of larva of *Simulium vittatum*, variety with small lobes at base. FIG. 7.—Rectal gills of larva of *Simulium bracteatum*, typical form. FIG. 8.—Rectal gills of larva of *Simulium pictipes*, typical form. FIG. 9.—Rectal gills of larva of *Simulium venustum*, typical form. All greatly enlarged. (Original.)

quire swiftly flowing water for their development. The full-grown larva of the largest species, according to Johannsen, measures not more than 15 mm. in length. The American species known to the writer measure from 12 mm. (*S. pictipes*) to 3.5 mm. (*S. jenningsi*). The larvæ are generally subcylindrical, somewhat attenuated at the middle, and with a gradual dilation toward the anal extremity. In addition to the head there are 12 rather indistinct body segments.

FIG. 3.—*Simulium bracteatum*. Antenna of larva. Greatly enlarged. (Original.)

In the larval stage the shape and number of the branches of the rectal gills seem to be good systematic characters, not differing essentially among individuals of the same species. If the number and length of the antennal joints, the teeth in the mentum, and the character of the dorsal markings of the head are also used, the determination of half-grown larvæ is possible. The larvæ in their last stage can be correlated positively with their respective pupæ by the dissection and study of the pupal filaments, which become fully developed under the larval skin.

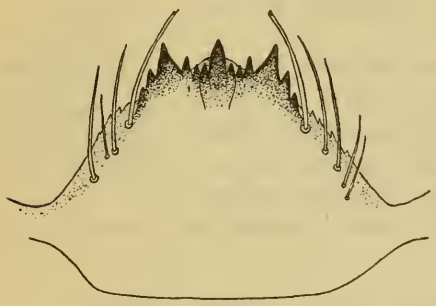


FIG. 4.—*Simulium bracteatum*. Labial plate of larva. Greatly enlarged. (Original.)

As the larvæ of *S. bracteatum* and *S. jenningsi* have not been previously described, the following descriptions are given.

DESCRIPTION OF LARVA OF SIMULIUM BRACTEATUM.

The full-grown larva is from 6 to 6.5 mm. in length. The general color varies from light yellowish-brown to grayish, with conspicuous brownish markings on the ventral surface. The antennæ (fig. 3) are slender, 4-segmented;[1] the second segment one and one-half times as long as the first; the third segment as long as the first; the fourth a short conical process; the general color pale hyaline; the first segment infuscate.

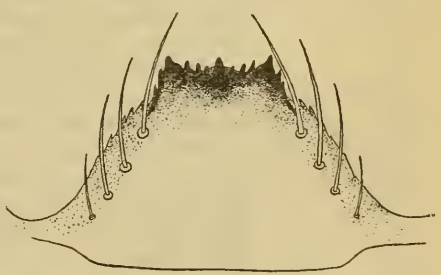


FIG. 5.—*Simulium venustum*. Labial plate of larva. Greatly enlarged. (Original.)

The labial plate (fig. 4) is more strongly serrate than that of *S. venustum* (fig. 5): the apical margin rather convex; the middle tooth and each corner tooth very large. There are from four to five long bristles near the lateral margin on each side.

[1] The writer differs from other writers in regard to the segmentation of the antennæ.

The head (Pl. III, fig. 7) is light brownish-yellow in color, heavily marked with brown on the lateral margins. The dorsal markings of the head are arranged in the form of a long central irregular blotch, with two adjacent blotches extending diagonally on either side.

FIG. 6.—*Simulium bracteatum*. Row of spines from caudal sucker of larva. Greatly enlarged. (Original.)

The mandibles are similar to those of *S. venustum* (fig. 12), but darker in color. The maxillæ are infuscate and very hairy; the proximal portion of the maxillary palpus is dark brown, with a few sparse hairs; the distal end transparent, bearing a few conical processes.

The rectal gills (Pl. IV, fig. 7) are simple, three branched, somewhat pointed toward the distal end, and are curved backward cephalically when extended.

The caudal sucker bears from 60 to 70 rows of spines or hooks (fig. 6).

FIG. 7.—*Simulium jenningsi*. Antenna of larva. Greatly enlarged. (Original.)

The larvæ were taken by the writer from several streams in the vicinity of Spartanburg, S. C., from June to October, 1913. They were separated from the larvæ of other species by the number of the branches of the pupal filaments (formed underneath the larval skin) and determined from adults reared from them and compared with the type.

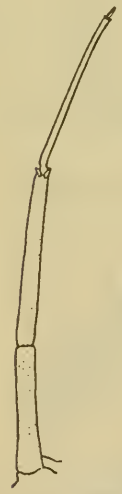


FIG. 8.—*Simulium venustum*. Antenna of larva. Greatly enlarged. (Original.)

DESCRIPTION OF THE LARVA OF SIMULIUM JENNINGSI.

The larva of *Simulium jenningsi* is much smaller than that of *S. venustum* and measures from 3.5 to 4.5 mm. in length. The general color is light brownish yellow. The head is of a uniform yellow with dark-brown blotches of characteristic arrangement on its dorsal surface (Pl. IV, fig. 3), thus differing from *venustum* (Pl. IV, fig. 4), which usually has the pigment in these cells lacking. The antennæ (fig. 7) are slender and 4-segmented, the last segment being a short conical process; the first three segments are subequal in this species, while the antennæ of *venustum* (fig. 8) have the second segment longer than the first. The labial plate (fig. 9) is broader than that of *venustum* (fig. 5) the teeth more even and equal in size, the middle tooth not very prominent, and there are apparently only two large and one small bristle along each margin, while *venustum* has four to five large bristles on each side.

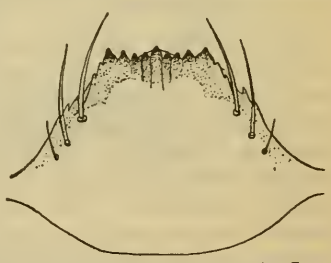


FIG. 9.—*Simulium jenningsi*. Labial plate of larva. Greatly enlarged. (Original.)

The mandibles are of the usual type, but rather weak and the teeth somewhat pale.

The rectal gills (Pl. IV, fig. 5) are three-branched, each lateral branch bearing six lobes and the middle branch five, as a rule. This is a smaller number of lobes than is found in *venustum* (Pl. IV, fig. 9), which has seven or eight on each lateral branch.

The caudal sucker bears from 70 to 75 rows of hooks.

The larvæ were taken by the writer from a fair-sized stream near Spartanburg, S. C., in August, 1913, and were separated from the larvæ of other species by the number of branches of the pupal filaments (formed underneath the larval skin) and determined from adults reared from them and compared with the type.

FIG. 10.—*Simulium pictipes*. Antenna of larva. Greatly enlarged. (Original.)

EXTERNAL AND INTERNAL STRUCTURES OF THE LARVÆ.

The head is more or less quadrangular in shape and very chitinous. The eyes have become reduced to mere pigment cells, in the shape of two irregular black blotches, situated on each side of the head.

In addition to the usual mouth parts, the head bears a pair of peculiar fan-like organs, situated one on each side at the anterior end. The rays or cilia of the fans are attached at the base each by a strong peduncle and range in number from 30 to 60 according to the species. On the inner margin of these cilia are fringes of short hairs interspersed with minute teeth. As the number of cilia varies in individuals of the same species, they are not very reliable specific characters. The fans, acting as strainers, catch the microorganisms on which the larvæ feed and sweep them into the mouth.

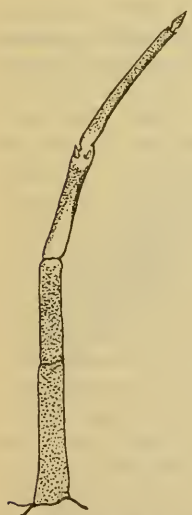


FIG. 11.—*Simulium vittatum*. Antenna of larva. Greatly enlarged. (Original.)

The antennæ (figs. 3, 7, 8, 10, 11) are situated at the sides of the head, on the dorsal surface toward the cephalic end, just below the base of the fans. They are slender, and in the species examined, naked. Johannsen says "The antennæ are apparently jointed * * * the first joint twice as long as the others taken together; the second, slender cylindric * * * the third joint a short pointed process at the apex of the second." Miall says "Small three-jointed antennæ" and gives a figure in which the antennæ have three long joints and lack the short pointed process forming the last joint. Of the five species dealt with in this paper, the larvæ of *Simulium venustum* (fig. 8), *S. pictipes* (fig. 10), and *S. bracteatum* (fig. 3)

have the antennæ 4-jointed, the first long joint described by Johannsen being divided by a very distinct suture. Though the first and second joints are very closely articulated and rigid, the constant occurrence of a distinct suture between them seems to indicate clearly the existence of two segments. The third segment is slender cylindrical, and the fourth a short conical process.

There are two conical processes situated at the apical end of the second segment, which seem to be sense organs. The antennæ of *S. vittatum* (fig. 11) are 5-segmented, the second segment being again divided. The sense organs are borne on the apical end of the third segment. In color the antennæ vary with the species from yellowish hyaline to dark brown.

FIG. 12.—*Simulium venustum.* Left mandible of larva, ventral view. Greatly enlarged. (Original.)

The mandibles are situated just below the fans and move horizontally. With the exception of a slight difference in size, according to the species, there are no constant characters of real systematic value in the mandibles.

The following is a description of the mandibles of *S. venustum:*

The mandibles (fig. 12) are very chitinous, stout, somewhat elongate, with the outer lateral margin rounded. There are from two to four large teeth at the apex on the inner lateral margin, almost dense black in color. Situated immediately dorsad along the inner margin of the largest tooth is a row of from six to eight smaller teeth of the same shape, but much lighter in color and gradually decreasing in size. Behind this row, on the ventral surface of the mandible, arising generally from the third or fourth tooth, is a second row of small, sharp-pointed teeth very pale in color, about 10 to 14 in number, which continues along the basal portion of the lateral margin of the largest apical tooth. Laterad of this second row of teeth, on the inner margin of the mandibles, there is a large wide-angled flattened tooth, very pale in color, followed by a smaller one of the same description. Near the apex of the mandible, a short distance from the outer lateral margin of the ventral surface, are two large bristles arising from almost the same point. At the base of the large apical teeth, on the ventral surface, are two clumps of stout hairs. There is a fringe of long hairs on the dorsal surface of the mandible, which extends halfway down, commencing at the apex, where it almost obscures the apical teeth. Opposite the base of this fringe on the inner lateral margin of the mandible there is a fan of long hairs, and a fringe of very long hairs, which continues down to the base, gradually developing into bristles explanate and divided at apex.

The maxillæ are situated immediately ventrad and mesad of the mandibles. The maxillary palpus is short, cylindrical, and bears on its distal end several small cone-shaped protuberances similar to

those borne on the third segment of the antenna. The lacinia bears mesad and cephalad fringes of long hairs and bristles. On its distal end there is a single spurlike process.

The labrum is short, rounded, fringed with long hairs, and is situated overhanging the hypopharynx. It is reinforced on its dorsal surface by a strong T-shaped sclerite. The apical margin is sometimes serrate.

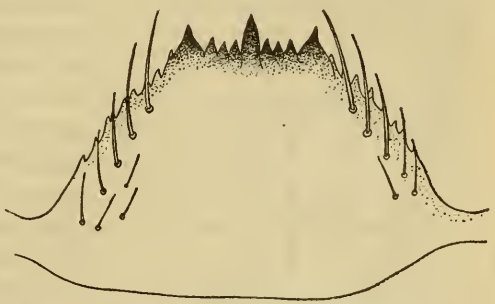


FIG. 13.—*Simulium vittatum.* Labial plate of larva. Greatly enlarged. (Original.)

The labium (figs. 4, 5, 9, 13, 14), which almost covers the ventral surface of the hypopharynx, is composed of two or more broad chitinous united plates. It is immovable. The apical edge of the ventral plate is serrate. The lateral and apical margins of the dorsal plate are also serrate and the apical margin usually bears a very prominent central tooth. In some species the teeth are trifid, and in others simple. There is a row of from three to 10 long bristles near each lateral margin of the ventral plate. The number and shape of the teeth and the arrangement of the bristles are of systematic value in separating the different species, and Robaud and Malloch[1] consider these characters to be of possible generic value. There is a certain amount of individual variation, but seemingly within definite limitations.

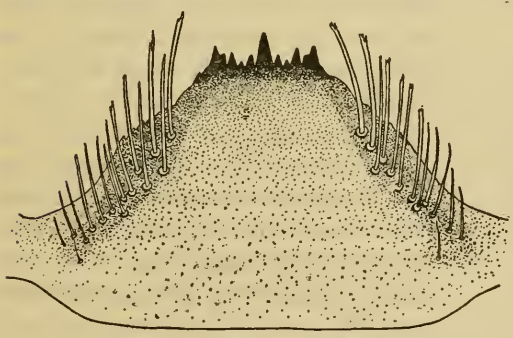


FIG. 14.—*Simulium pictipes.* Labial plate of larva. Greatly enlarged. (Original.)

The dorsal portion of the head in most species has distinct markings of very characteristic arrangement. (Pl. IV, figs. 1–4.) Though subject to a certain amount of individual variation, they are of systematic value in separating the different species especially when combined with other more constant specific characters. These markings are formed by a collection of large cuticular cells which, in some species, such as *S. vittatum*, are strongly pigmented, while in others, such as *S. venustum*, they are normally almost devoid of pigment, the surrounding area being dark.

[1] Malloch, J. R. American black flies or buffalo gnats. U. S. Dept. Agr. Bur. Ent. Tech. Ser. no. 26, 71 p. (p. 8), 6 pl., 1914.

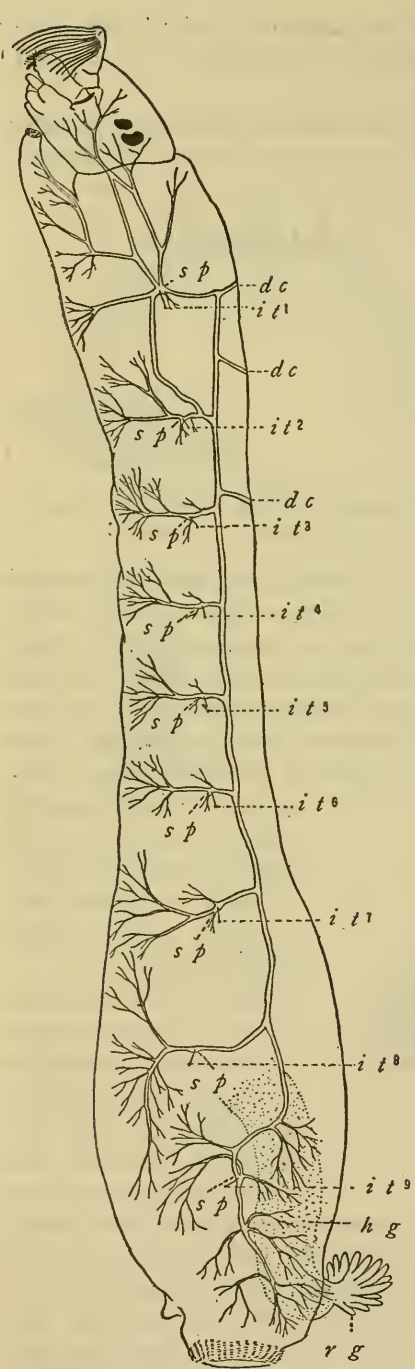


FIG. 15.—*Simulium venustum.* Tracheal system of larva: *dc, dc, dc,* Dorsal commissures; *it,* initial threads; *sp*(9), spiracular chambers; *hg,* hind gut; *rg,* rectal gills. Greatly enlarged. (Original.)

The thoracic proleg of Simulium larvæ consists of a single elongated, truncate process, attached to the second thoracic segment and bearing concentric rows of minute hooks at its apical end, which is cup-shaped, and capable of muscular contraction, thus forming a suckerlike organ, used by the larva as means of attaching itself. A somewhat similar but very much larger suckerlike disk is situated at the caudal extremity of the larva. The rim is composed of rows of strong chitinous hooks as in the proleg. The number of rows ranges in the different species from 50 to 140, and the number of hooks in a row from 8 to 30. There is so much individual variation in the number of rows and the number of hooks in a row that they are not of much systematic value. The average number of rows in the caudal disks of five species is as follows: *S. jenningsi*, from 70 to 75; *S. venustum*, from 55 to 65; *S. bracteatum*, from 60 to 70; *S. vittatum*, from 65 to 85; *S. pictipes*, from 130 to 140. *S. pictipes* has by far the greatest number of rows, very close together and from 25 to 30 hooks in each row. It is the only one of these five species that can be positively determined on these characters alone.

RESPIRATORY SYSTEM OF THE LARVÆ.

The tracheal system of the larva (fig. 15) consists of two main longitudinal trunks, connected by commissures, which lead to the spiracular chamber. Extending from the spiracular chambers are thin chitinous rods (the initial threads), which lead to the oval

thickenings of the cuticle known as the spiracles. The spiracles do not seem to be functional as a means of respiration.

Respiration apparently takes place by what are known as the rectal gills (Pl. I, fig. 2, *rg*), which are extensions of the rectal wall and are formed of the same epithelial layer. These extensions are primarily 3-branched, and are either simple or bear numerous lobes. Minute tracheolæ penetrate these gills, joining the main trunks at the base of the rectum. The gills are also filled with blood, are retractile into the rectum, but are usually extended in running water. According to Headlee, they function both as blood gills and as tracheal gills, as the presence of blood in them is undoubted, and since the tracheæ in them are very minute. The tracheal system can be seen very distinctly in living larvæ. Several larvæ, still quite active, were placed in a shallow dish of water and examined under the binocular by the aid of strong sunlight against a black background. As the larvæ slowly died the tracheæ, owing to the air collected in them, showed a bright silvery appearance, so that even the very small ramifications and branches could be clearly distinguished. The larvæ seem to be in a comatose condition an hour or so before death, and the silvery appearance of the tracheæ remains for about three hours after death, so that there is a considerable period in which the tracheæ may be studied before the air is driven out. In larvæ preserved in alcohol or mounted in balsam the air, of course, is driven out of the tracheæ, which becomes almost transparent, so that it is very difficult to trace them in this condition. The tracheæ become greatly ramified toward the caudal end of the body and seem to penetrate the wall of the alimentary tract and to extend into the rectal gills.

Larvæ have not been found to survive longer than forty-eight hours in still water, and on being transferred from flowing water will turn back constantly in an effort to clean the rectal gills with the mouth parts. Larvæ placed in still water and only barely covered will survive longer than those covered to a depth of 3 inches or more. That the lack of oxygen is responsible for the death of the larvæ transferred from flowing to still water is further evidenced by the fact that the larvæ will survive longer in a tightly corked bottle at a temperature of 32° F. than at a temperature of 75° F., because the amount of oxygen that can be held in solution by the water varies inversely as the temperature. Larvæ seem to thrive equally well in running water, whether the temperature is 32° or 75° F. Low temperature seems to retard but not to injure development, and a rising temperature up to 75° F. hastens development.

The structure of the rectal gills and the number of lobes afford excellent systematic and specific characters, as may be seen from the accompanying figures (Pl. IV, figs. 5–9). The variation in individuals seems to be bounded by well-defined limitations.

LARVAL DEVELOPMENT.

From 12 to 16 hours before hatching the young larvæ are in an apparently free condition within the shell. There is an almost continual movement of the head, which is forced against the ectoderm by sudden convulsive movements of the body. The shell suddenly splits and the larva at once emerges, literally tumbling out. The split reaches from the cephalic end of the egg to the middle, generally a little to the left. It is evident from the clear appearance of the alimentary tract of the newly emerged larva that the ectoderm is not eaten away at all. The larva at once clings to the nearest point of attachment by its thoracic proleg and waves its anal portion around several times, evidently to clear the rectal gills. It then attaches itself to the nearest object by the peculiar suckerlike organ on its anal extremity and thrusts out its gills at intervals of about 15 seconds. It at once commences to feed on the matrix surrounding the eggs and the adjacent microorganisms, using its thoracic proleg as a scoop, with a constant movement of this organ toward the mouth parts. In still water the fans are not used for sweeping in the food for some hours after the larvæ have hatched, but remain appressed to the sides of the head.

The newly hatched larvæ of all the species described in this paper measure from two-thirds to three-fourths of a millimeter in length. The structure of the larvæ in the first instar, of the species examined by the writer, is fundamentally the same as in the last, with the exception that the head is larger in proportion to the rest of the body and the general appearance very transparent, due to the lack of pigmentation and the empty condition of the alimentary tract. The black eye spots on the sides of the head are very prominent, and the dorsal markings of the head, though not so distinct as in later stages, are easily distinguishable. The silk glands are employed almost at once after hatching to form a silken thread, which is used to hold the larva in position in the current. The structure of the rectal gills seems to remain the same throughout larval development.

LARVAL HABITS.

MOLTING OF THE LARVÆ.

According to Strickland[1] the larvæ do not shed the entire skins but only the skeleton of the head. The writer has found that the entire skin is shed, as larvæ have been found which had partly cast off the entire skins, bearing the chitinous hooks of the caudal sucker, and which showed the caudal sucker again developed in the new larval skin. The entire skeleton of the head is cast off toward the

[1] Strickland, E. H. Some parasites of Simulium larvæ and their effects on the development of the host. (*In* Biol. Bul., v. 21, no. 5, p. 302–338 (p. 303), 5 pl., Boston, 1911.

front at molting, and the remainder of the skin toward the caudal extremity, the tracheæ being withdrawn through the spiracular openings. The number of molts has not been determined.

MIGRATORY HABITS AND LOCOMOTION OF THE LARVÆ.

On being suddenly disturbed or on the diminishing of the current, the larvæ let themselves be carried down stream steadied by the silken thread previously described, which they have attached to some stationary object, and seek a more favorable situation. In many instances the larvæ have been observed almost to regain their former position, by winding up the thread with the thoracic proleg and mouth parts, but as a rule they are unable to work against the current. The method of locomotion in still water is similar to that of geometrid larvæ. By looping the body, they bring the anal extremity forward beside the proleg, which is then released on the caudal sucker again obtaining a firm hold.

A heavy rain causing a sudden swiftening of the current will often entirely change the distribution of the larvæ. This fact is of considerable economic importance, as it may account for the sudden appearance of Simulium in localities usually exempt. This was well illustrated in the following instance, observed by the writer at Spartanburg, S. C. A fair-sized stream had been free from larvæ for two months or more, when one of the tributaries near its source became heavily infested with young and half-grown larvæ. A heavy rain and consequent washout carried practically every larva from the tributary down the large stream for nearly a mile, where they became successfully established, causing a subsequent heavy infestation.

Young larvæ seem to migrate more readily than full-grown larvæ. Several experiments were tried in regard to this. A vessel containing larvæ of all sizes was placed under a running faucet, causing the vessel to overflow. The full-grown larvæ as a rule remained in the comparatively still water within the vessel, often spinning their cocoons and successfully pupating. The young and half-grown larvæ seemed invariably to detach themselves and would be found within two hours gathered on the surface over which the water was flowing.

At one time the attention of fish culturists was drawn to Simulium, as the larvæ were stated to cause the death of young trout by entangling them in a silken web. This was disproved in the American Entomologist and Botanist, in 1870, by Mrs. Sarah J. McBride,[1] who clearly demonstrated that the "death web of young trout" was a myth, and that the threads were not strong enough, or interwoven, so that fish could be entangled in them.

[1] See Bibliography, p. 35.

THE FOOD OF THE LARVÆ.

The food of the larvæ is entirely microscopic. There are various accounts given on this subject by different authors, and they are somewhat divergent. Riley says that they feed on animalcules, but do not disregard microscopic matter of vegetable origin. He also states that larvæ kept in a jar were seen to swallow the minute larval forms of small crustaceans belonging to the Copepoda and Isopoda, and that a number of square diatoms, joined together in chains, were found in the alimentary tract.

Miall says that he has found in the alimentary tract flinty valves of diatoms, desmids, and pieces of small crustaceans.

Kellogg, in his article on the food of Simulium and Blepharocera, states that he found thousands of tiny siliceous shells of diatoms in the intestines. They caused considerable difficulty in the making of microscopical sections for histological study. He also states that the larvæ feed on the stalked Gomphonema and occasionally on the genus Nitzschia. They are also stated to feed on Vaucheria and Nothrix.

The writer has found that the color of the larva varies according to the nature of the stream, and that the larvæ seem to thrive best in streams containing the largest proportion of such organisms as *Euglena viridis* and Spirogyra. Larvæ in running water were observed feeding in specially constructed glass tanks, and were seen to reject large Paramoecia and apparently anything except the smallest particles of the plankton. A striking fact seemed to be the effect of different foods upon the color of the larvæ. When the tank containing the food of the larvæ was filled only with water, decaying vegetable matter, and living grasses, the larvæ became emaciated and starved to death; but on the introduction of green algæ and Spirogyra, they regained their vitality and the alimentary tract changed from a light brownish yellow to a bright green. Dissections of the alimentary tract showed normally a quantity of green rod-like algæ, flinty shells of diatoms, and some minute star-shaped animalculæ. The larva of *Simulium pictipes*, which lives in the larger streams, has the alimentary canal filled with a quantity of sand; and the color is always brown corresponding to the brown growths on the rocks. The streams in South Carolina, which were contaminated by chemical refuse from the cotton mills, were absolutely free from larvæ, and this fact is of economic importance as it may be utilized further in the control of the larvæ. Pure animal sewage is not deleterious to the growth of the larvæ, provided the other environmental factors are favorable.

THE PUPAL STAGE.

METHODS OF PUPATION.

The histoblasts of the pupal and adult organs are formed in Simulium larvæ some considerable time before pupation takes place, and can be discerned when the larvæ are half grown, shortly after the second molt. The pupal respiratory organs, composed of long tubelike filaments (Pl. V, fig. 1), can be seen underneath the larval skin, on the sides of the anterior portion of the thorax, lying coiled up and visible as rounded darkened areas which become almost black as the pupal stage approaches. (Pl. III, fig. 7, A, A.) Shortly after the molt preceding pupation the chitinous hooks on the dorsal and ventral surfaces of the abdomen of the pupa become well developed underneath the larval skin.

Before commencing to pupate the larva spins over itself a pocket-shaped pupal case, formed of the strong silken threads supplied by the salivary glands. The shape and texture of the pupal cases vary according to the species. Of the five species discussed in this paper, four have pupal cases of the shape that may be described as the "wall-pocket" type, the texture finely spun, almost leathery in appearance, the cases being spun as a rule well separated from one another, and the distal end wide and rather open. (Pl. V, fig. 2.) *S. pictipes* is the exception, having the pupal case shaped after the fashion of a boot (Pl. V, fig. 5), the heel always pointing downstream, the pupal cases often overlapping one another in a coral-like formation, the texture coarsely spun, very tough, and the distal end narrow.

Shortly before the larva has finished making the pupal case the air from the tracheæ, entering the extension leading from the base of the main trunk from which the branch filaments arise, slowly creeps along the entire length of the filaments. The skin splits along the dorsum of the thorax and the filaments are at once projected into the water. The skin behind the head is then worked off toward the caudal end of the larva and the old tracheæ are withdrawn through the spiracular openings. The inner lining of the hind gut, together with the anal gills, which are formed of the same epithelial layer, is then cast out through the anal slit which is situated just above the X-shaped sclerites on the dorsal surface at the posterior end of the larva, and may be seen attached in the interior of the cast larval skin, which often remains for a while within the pupal case. The skeleton of the head of the larva is then pushed off downward to the front, the wall of the alimentary canal, about as far as the junction of the pharynx and the œsophagus, coming away with it. The pupa seems to lock itself in the pupal case by means of the

strong hooks on the dorsal and ventral surfaces of the abdomen. These hooks are turned anteriorly on the dorsal surface on segments 2, 3, and 4; posteriorly on the dorsal surface of segments 7, 8, and 9, and all hooks on the ventral surface are turned anteriorly. The whole operation of pupation and of spinning the pupal case takes from 45 minutes to 1 hour.

GENERAL DESCRIPTION.

The pupæ of Simulium at first are generally golden yellow or light brown, the color and shape of the adult organs showing very clearly through the pupal skin as the time of emergence approaches. There are nine abdominal segments. On each side of the thorax are situated the respiratory organs, composed of long chitinous tubes, arising from a main stalk, tapering somewhat, and usually branching dichotomously toward the distal end. The number of filaments, always counting the branches of the distal ends, varies according to the species, from 4 to 60, and is an excellent systematic character, as it is very constant for each species. On the dorsal and ventral surfaces of the abdomen are situated rows of strong chitinous hooks. These seem to be of little use as distinguishing characters for the five species discussed in this paper, as they are approximately the same in number and have about the same position in each. The pupæ can be positively correlated with the adults by the dissection of mature male pupæ and study of the genitalia.

The pupæ of *S. bracteatum* and *S. jenningsi* have not been previously described, and the following descriptions are given:

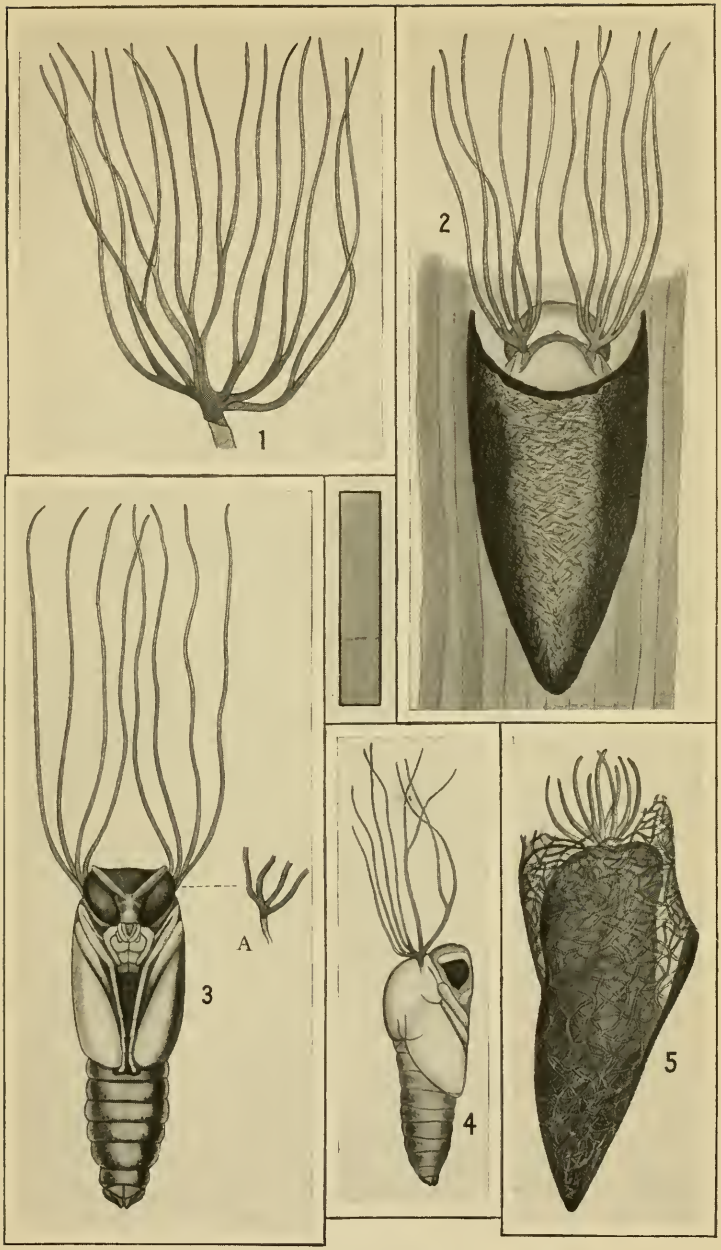
DESCRIPTION OF PUPA OF SIMULIUM JENNINGSI.

The pupa of *S. jenningsi* (Pl. V, fig. 4) is not more than 2.5 mm. in length, and is golden yellow when first formed.

The respiratory filaments, which are situated at each side of the thorax near the head, are each composed of a single main trunk, which divides at base into the following branches: Four single unbranched filaments and two long filaments, each of which divides again dichotomously, making eight branches in all, counting the distal ends of the branches.

On the dorsal surface of the abdomen there is a row of very small hooks on each side of the second segment, and on the third and fourth segments rows of four very large hooks on each side pointing cephalad. On the fifth segment there is a row of hooks pointing caudad, and on the ninth segment a row of minute hooks near the cephalic margin and a single large hook on each side at the middle of the segment. On the ventral surface of the abdomen there are two large hooks close together on the fifth segment, and two large hooks, rather far apart, on each of the sixth and seventh segments. The caudal end of the pupa is cleft for a short distance in the middle.

The pupæ studied were reared from larvæ and determined from adults reared from them and compared with the type.



PUPÆ OF SIMULIUM.

FIG. 1.—Respiratory filaments of pupa of *Simulium vittatum*. FIG. 2.—Pupa of *Simulium venustum*, in pupal case. FIG. 3.—Pupa of *Simulium bracteatum*: A, side view of filaments. FIG. 4.—Pupa of *Simulium jenningsi*. FIG. 5.—Pupa of *Simulium pictipes*, in pupal case. All greatly enlarged. (Original.)

DESCRIPTION OF PUPA OF SIMULIUM BRACTEATUM.

The pupa of *S. bracteatum* (Pl. IV, fig. 3) measures about 4 mm. in length and is of a golden yellow color when first formed.

The respiratory filaments are composed of a single main trunk on either side of the thorax, each of which divides in the following manner: Two long branches arise from the base of the main trunk, which again divides a short distance farther up, making four long branches on each side, counting the branches at the distal ends. The hooks on the abdomen are arranged as usual.

The pupæ were reared from larvæ and determined from adults reared from them and compared with the type.

DURATION OF PUPAL STAGE.

The duration of the pupal stage of *S. venustum*, according to Mrs. Sarah J. McBride, at Mumford, N. Y., is three weeks. The maximum period in the pupal stage of the same species observed by the writer was nine days at Havana, Ill., late in the fall, the average temperature during that period being 36° F.

The minimum period in the pupal stage of *S. venustum* was a little over 84 hours at Spartanburg, S. C., during the month of June, with a temperature from 70° to 90° F. The average length of the pupal period for the five species under consideration, during the summer, is from five to seven days.

The general effect of low temperature seems to be to retard, and of rising temperature up to 90° F. to hasten the emergence of the adult from the pupa. The effect that low air temperature has on the pupa in retarding development is much less in proportion than the effect that a rising temperature between 60° and 80° F. has in hastening emergence. Though their structure is normally adapted for aquatic life, yet when they are exposed to the air, as sometimes happens when the water falls, they will often emerge even after 24 hours spent out of water if the adult is sufficiently developed within the pupal skin. This was especially noticeable at Havana, Ill., in 1912, when the river began to fall.

The respiratory system of the pupa is a modification of the general tracheal system of the larva. The rectal gills having been cast off, their function appears to be assumed by the tubelike filaments arising on each side of the thorax. There are two long main trunks extending down each side of the abdomen. These give off branch tracheæ, connected by commissures, which lead to the abdominal spiracular chambers, from which arise the initial threads leading to the spiracles. The spiracles are cuticular invaginations and become closed, according to Taylor,[1] on the withdrawal of the old tracheæ at the time of the

[1] Taylor, T. H. On the tracheal system of Simulium. *In* Trans. Ent. Soc. London, f. 1902, p. 701–716 (p. 703), 8 fig., 1902.

shedding of the larval skin. From the mesothoracic spiracular chamber extends a broad tracheal trunk leading to the base of the main trunk of the respiratory filaments, which do not contain tracheæ, but are hollow. According to Taylor,[1] the air is not taken directly into the gill base from this hollow space, but is absorbed through the external chitinous fibrillæ and thence into the tracheal extension through a membrane.

EMERGENCE FROM THE PUPAL STAGE.

Four or five hours before emergence there is a very noticeable intermittent movement of the adult within the pupal skin, which is gradually distended with air toward the anal extremity, the abdominal tracheæ being probably withdrawn through the spiracular openings. Coincident with this the anal portion of the adult is withdrawn from the pupal skin and a threadlike membrane, seemingly the lining of the hind intestine, may often be seen extending from the anus of the adult to the pupal skin, to which it remains attached after emergence. As the pupal skin is locked by the strong chitinous hooks to the pupal case, the adult exerts a strong pressure toward the cephalic end and the pupal skin splits along the dorsal portion of the thorax and head, forming a T-shaped aperture. The adult at once rises to the surface of the water surrounded by a bubble of air which has been collected in the distended pupal skin, and running along the surface of the water at once takes flight. The curious way in which the adult rises to the surface surrounded by a bubble was commented on by the earliest writers on the group, and in situations where the pupæ are found in thousands, as in parts of Hungary, and along the Illinois and Mississippi Rivers in America, the water seems almost to boil as they emerge.

LIFE CYCLE AND NUMBER OF GENERATIONS.

The number of generations varies according to the species and the latitude. In the Southern States the species seem to breed continuously from about the middle of March until the approach of severe cold weather, generally about the end of November. The life cycle of one generation during the summer takes approximately four weeks; 7 days in the egg stage, 17 days as larvæ, and 4 days as pupæ. The time from the egg to the adult stage varies according to the rise and fall of the temperature. There are probably from five to six generations annually in South Carolina of the species here dealt with, except *S. pictipes*, which normally has three generations. In Illinois there are only three or four generations of *S. venustum* annually.

[1] Loc. cit.

INSECT ENEMIES AND PARASITES.

The larvæ of Simulium are often parasitized by nematode worms of the genus Mermis, specimens of which have been found by the writer measuring 12 mm. in length. These were found in larvæ of *S. venustum*, coiled around the intestines, and extended from near the caudal end to the thorax. The specimens that attained the greatest length were found singly, but as many as four have been found in individual larvæ. According to Strickland (1911),[1] the Mermis retard the development of the pupal and adult histoblasts, cause the death of the larvæ, and escape through punctures made in the epidermis. He also states that in the vicinity of Boston, Mass., Mermis was found parasitizing larvæ only during the spring, and that there is a seasonal variation of parasitism. The writer, while in South Carolina, found species of Mermis parasitizing larvæ from May until late in October, and these larvæ seemed to have developed the pupal histoblasts to a much greater extent than is estimated by Strickland. The larvæ are also heavily attacked by glugeid and gregarine species of Myxosporidia.

The writer has found the larvæ being attacked by species of Hydropsyche in Illinois and South Carolina. Dr. Howard (1888)[1] also mentions this fact in his article on a species of Simulium at Ithaca, N. Y., and gives a fuller account in the Annual Report of the U. S. Commissioner of Agriculture for 1886, page 510. Species of minnows attack the larvæ frequently, and Riley[2] mentions that the small fishes of the family Cyprinidæ also feed on them.

The pupæ, so far as is known, are not parasitized by Mermis or Myxosporidia. The adults have been found by the writer at Spartanburg, S. C., to be frequently parasitized by nematode worms of the genus Mermis, which were usually found singly. In one instance three of the worms were found in a female *S. venustum*. The same number were found in a female of *S. bracteatum*. They were situated in the abdomen, coiled around the Malpighian tubes and intestines, and in some cases extended into the thoracic region. The vitality of these specimens infested by the Mermis seemed to be seriously affected, though they lived for some time, 31 hours being the minimum and 72 the maximum period. All of these specimens thus parasitized were reared from pupæ, with the exception of one adult female of *S. bracteatum*, which was taken flying around a lamp at night. No adults taken biting on animals were ever found to contain Mermis.

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[1] See Bibliography, p. 35.

[2] Riley, C. V. Report of the Entomologist. *In* Rept. U. S. Comr. Agr. f. 1886, p. 459–592 (p. 510), 11 pl., 1886.

Georgewitch[1] describes a trypanosome, *Crithidia simuliae*, which he found in the stomachs of adult females taken biting cattle, etc. The locality in which the animals were attacked was a district in Servia, and the species *S. reptans* (=*S. columbaschense*). He did not, however, find any similar organism in the blood of the animals attacked.

Riley[2] states that Lugger observed them being attacked by Asilidæ and Odonata.

Wise (1911)[3] reports that in British Guiana the adult females of Simulium are attacked by a voracious enemy in the nature of a black and white wasp (probably *Monedula signata*), which follows the aboriginal Indian to obtain the "Pium" (Simulium). This wasp reduces the "Pium" to unconsciousness, deposits eggs, and leaves the body to be fed upon by the resulting larvæ.

SIMULIUM AS A POSSIBLE CARRIER OF DISEASE.

In 1874 J. P. Megnin[4] strongly advanced a theory that two species of Simulium in the Department of the Rhone, France, are the transmitting agents of virulent charbon. He also mentions Stomoxys and Haematobia in this connection, but places most emphasis on Simulium, whose habits more closely conform to the outbreaks and distribution of the disease in that locality. He also states that, in his opinion, M. Tisserant, sent by the French Government to investigate the subject, proved that Simulium was the cause or the transmitting agent of the disease. In a later paper he reaffirms his statements and mentions that he has found a "Psoriasis guttata" prevalent in the ears of horses, and believes it is due to the bites of Simulium. The writer has found a similar condition to be very common in the ears of horses, undoubtedly due to the bites of Simulium, in Illinois, South Carolina, and the vicinity of Washington, D. C. As this condition may be of a purely secondary nature, and as apparently no experimental or careful analytical work has been done on the subject, all statements regarding the transmission of a disease of cattle by Simulium must be regarded as purely theoretical.

According to Riley and other authors, *S. pecuarum* Riley and *S. meridionale* Riley were supposed to carry cholera among chickens and hogs, but nothing definite was ascertained on this point.

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[1] Georgewitch, Jivoin. Sur un Trypanosomide nouveau, *Crithidia simuliae*, n. sp. d'une Simulie (*Simulium columbacensis*) de la Serbie septentrionale. *In* Compt. Rend. Soc. Biol., t. 67, no. 31, p. 480–482, 1 fig., Nov. 12, 1909.

[2] Op. cit., p. 510.

[3] See Bibliography, p. 35.

[4] Du role des mouches dans la propagation du charbon et autres affections virulentes. *In* Jour. Med. Veter. Mil., t. 12, no. 8, p. 461–475, Paris, Jan., 1875.

In 1905 Dr. Louis Sambon advanced the theory that pellagra might be transmitted by a blood-sucking fly of the genus Simulium. An accurate knowledge of the biology of the genus is very necessary in order to prove or disprove such a theory. It must be proved that Simulium not only bites in very large numbers, in order that a sufficient percentage of specimens will become infected which will live and become capable of transmitting pellagra, but it must also be proved that they will bite man after they have become infected, since hereditary transmission is probably entirely out of the question. Simulium exists in many places in large numbers, and if it should be proved that it normally requires a meal of the blood of vertebrates before it can fully develop the ovaries, then the chances that it may become infective are greatly increased.

Evidence on these points may be obtained in the following three ways:

(1) By rearing adult females from the immature stages, and then allowing them to engorge, oviposit, and reengorge. This method was tried a number of times, but with no success, for the fly will not readily engorge while in captivity, as was noted in the discussion of the feeding habits of the adult.

(2) By the capture of adults actually feeding on mammals, and by inducing them to oviposit and then to reengorge. This method also was unsuccessful for the same reasons.

(3) By dissections. If it could be proved that when a Simulium, which has once engorged on blood and oviposited, is still in a condition favorable to a second oviposition—that is, if rudimentary eggs are present in the ovaries awaiting only a second blood meal for their successful development—then there would be a more definite basis for a theory of disease transmission as opposed to the theory of merely a close coincidence in the distribution of pellagra and Simulium. This is the method adopted by the writer and is the one discussed in the following pages. The experiments were concluded in Spartanburg County, S. C., a country very favorable for the production of Simulium, being hilly and with a network of small streams, rapid and especially suitable for the development of the immature stages. The experiments on the actual biting and feeding habits were carried on more or less continuously from June 13 to September 16. The material for these experiments consisted of specimens of *S. venustum;* a good series of reared specimens (about 30); a number of females found engaged in oviposition; about 300 females all of which were taken in the act of engorging on mammals. Of the last named only about 90 were successfully dissected, as the engorged adults after death became internally disintegrated and hardened after an hour or so, despite every precaution. Many also died between midnight and 7 a. m., or while they were being transported from the place of

capture to the laboratory. The adults, with the exception of 10 specimens killed at the time of capture, were kept alive as long as possible and dissected as soon as death was imminent. Some, in order that data might be obtained on their condition at the time of engorgement, were killed when captured and dissected within an hour.

RECORDS OF DISSECTIONS.

DEVELOPMENT OF THE OVARIES OF REARED NONFED ADULTS.

In order to have a check on the experiments with engorged adults, 32 females reared from isolated pupæ were kept alive as long as possible, without food, in bottles containing damp cloths. There were a number of males, reared from this same lot of pupæ, at liberty within the breeding cage together with these females, and copulation probably took place, but no definite statement can be made with regard to this point. Four females were killed and dissected within 6 hours after emergence. The remainder lived from a minimum period of 14½ hours to a maximum of 119 hours. All these specimens on dissection contained rather transparent ovaries of great potential development and full of round eggs (stage 1) (Pl. I, fig. 1, p. 4). In no instance did any one of these specimens develop the eggs within the ovaries as far as even the second stage. The maximum longevity of any nonfed reared specimen exceeded the maximum longevity of any specimen taken after engorgement by 52 hours. It would seem, therefore, that of these 32 reared specimens, there would have been 1 or 2 which would have developed the eggs within the ovaries, if it had been in the natural course of events for them to do so.

CONDITION OF THE OVARIES OF FEMALES FOUND OVIPOSITING.

Eleven females were taken actually engaged in oviposition on grass blades in streams. When these specimens were dissected, there was found in each stomach a certain amount of substance closely resembling the digested blood found in engorged specimens which had lived after engorgement for 40 hours or more previous to their dissection. A chemical test for hæmatin was applied to the substance found in the stomachs of the females found ovipositing, in order to prove beyond doubt whether it contained animal blood or not, but, owing to the small quantity and the changes consequent to the process of digestion, it was impossible definitely to determine its character.

Three specimens were taken from grass blades in a stream on which they had just alighted and had not begun to oviposit. These specimens were at once dissected, and their ovaries were found to contain from 250 to 300 fully developed eggs. Four specimens were taken from egg masses deposited in the same situation, which had evidently

just finished ovipositing. Four others which subsequently laid from 89 to 349 eggs while in captivity were also captured. The adults lived after oviposition from 15 minutes to 67½ hours, and were dissected immediately after death. Their ovaries were found to contain in each case a large quantity of eggs of the round type corresponding to stage 1 (Pl. I, fig. 1) with the exception of the specimen which lived only 15 minutes after oviposition and in which the eggs within the ovaries were only visible under a high magnification. The ovary of one specimen contained in addition, near the oviduct, a large fully developed egg which had not been deposited. This last-mentioned condition (stage 5, Pl. 1, fig. 5) was also found in adults taken engorging upon mammals and killed at the time of capture.

CONDITION OF THE OVARIES OF ADULTS TAKEN FEEDING ON MAMMALS.

In order to demonstrate the relation between the amount of engorgement and its apparent effect upon the development of the eggs within the ovaries, the condition of the ovaries is discussed collectively with regard to the previous amount of engorgement by adults, irrespective of the dates on which the adults were captured.

The following symbols are used in description to separate the varying degree: (+) Slight and partial engorgement, or about one-fourth the utmost capacity; (++) fair engorgement, or one-half the utmost capacity; (+++) well engorged, or three-fourths the utmost capacity; (++++) complete engorgement, or distension of the abdomen to its utmost capacity.

CONDITION OF THE OVARIES OF ADULTS KILLED AT TIME OF CAPTURE.

Ten adults were taken from time to time engorging on the blood of mules. They were killed at once to obtain data on the condition of the ovaries at the time of engorgement. Two specimens were slightly engorged (+); in one the ovaries showed a condition corresponding to stage 5, each ovary containing about 12 fully developed eggs, the remainder of the ovary being filled with eggs of the round type; in the other the ovaries contained only eggs of the round type in large quantity (stage 1). One specimen was half engorged (++); its ovaries were in a condition typical of stage 5, being filled with small round eggs and containing in addition 8 large fully developed eggs in a free condition, which seem positively to have been developed at a different period from the rest of the ovaries. One specimen was fairly engorged (+++); the ovaries contained only eggs of the first stage in large numbers (stage 1). Six specimens were taken fully engorged (++++); all of the ovaries were in a condition typical of stage 1, the eggs being of the small round type, translucent, and in large numbers.

In conclusion, there were only two stages found in the ovaries of adults killed at the time of capture, either small, round, undeveloped eggs in large quantity (stage 1), or round undeveloped eggs with the addition of a very few large, fully developed eggs (stage 5). This latter stage is presumably the result of a previous engorgement and oviposition.

CONDITION OF THE OVARIES OF NONENGORGED ADULTS TAKEN ON ANIMALS.

Six specimens, which had evidently just alighted and had not fed on that particular animal, were taken at various times from mules' ears. They lived from 2 to 47 hours after capture, and the condition of the ovaries in all these specimens was typical of stage 1. There was no development of the eggs within the ovaries, and the condition seemed to be the same as in adults reared from pupæ and dissected shortly after emergence.

CONDITION OF THE OVARIES OF PARTLY ENGORGED ADULTS.

Twelve specimens were taken which had partly engorged (+). The eggs within the ovaries of five of these specimens were not developed at all, and showed a condition corresponding to stage 1. These lived from 16 to 30 hours after capture. Three specimens showed the ovaries in a condition typical of stage 5, with from 1 to 4 fully developed eggs near the oviduct, and with the remainder of the ovaries filled with the small round type. These individuals lived from 12 to 21 hours after capture. The ovaries of two specimens which lived for 52 and 53 hours, respectively, contained a large number of eggs between stages 2 (Pl. I, fig. 2) and 3 (Pl. I, fig. 3), almost oval in shape, about 200 in all. Two adults were slightly more engorged than the rest, though not quite half engorged. They contained ovaries with eggs fully developed, of the same size and shape as eggs freshly deposited, but in very small numbers as compared with those found in adults dissected before oviposition. There were about 30 eggs in the ovaries of one and 50 in the other, which lived 45 and 47 hours, respectively. These adults had possibly engorged once, oviposited, and then developed the remaining eggs in the ovaries.

In the condition of the ovaries of partly engorged adults these two points are worthy of notice: (1) No development of the ovaries took place unless the longevity of a specimen exceeded 40 hours; (2) stage 5 recurred in three cases.

CONDITION OF THE OVARIES OF HALF-ENGORGED ADULTS.

Five half-engorged (++) adults were taken. The ovaries of two specimens contained eggs of the round type typical of stage 1. They lived for 7 and 21 hours, respectively. One adult contained ovaries filled with eggs of the typical oval shape (stage 3) in large

numbers and dense white in color. This adult lived for 53 hours after engorgement. Two adults contained ovaries with fully developed eggs in small numbers. In one adult there were 25 eggs in each ovary and in the other 18. Both these adults lived for only 4 hours and 35 minutes after capture. This is probably a case of second feeding, because adults which lived for so short a period after engorgement could not have developed fully formed eggs in that time. The explanation of this condition is that they had probably deposited only part of the full number of eggs at a previous oviposition.

CONDITION OF THE OVARIES OF WELL-ENGORGED ADULTS.

Twelve well-engorged (+++) adults were taken on various dates, these specimens lived after capture from 7 to 47 hours. Only one specimen contained ovaries corresponding to stage 1. This specimen lived only seven hours and evidently had not had sufficient time in which to develop the ovaries. One specimen, which lived 17 hours, contained ovaries filled with eggs of stage 2, thus showing that the amount of development corresponds to the amount of engorgement and the requisite length of time after feeding. Six specimens, which lived from 17½ hours to 24 hours 45 minutes, contained ovaries filled with eggs of the oval type typical of stage 3, again showing a constant amount of development in proportion to the previous engorgement and subsequent longevity. One specimen, which lived for 43 hours, contained eggs of the oval type in a very small number, about 20 in each ovary, with the remainder of the ovary apparently filled with the eggs of the round type (stage 1). One adult contained ovaries with fully developed eggs, but only 27 in each ovary. This specimen lived for 30 hours. Two adults contained ovaries filled with fully developed eggs, over 100 in each ovary. These lived for 47 hours and evidently had the required factors, presumably a sufficient blood meal and sufficient time in which to digest, in order to develop the eggs within the ovaries.

The foregoing data seem to show again that the development of the eggs within the ovaries is increased by the amount of food plus the length of the period of digestion.

CONDITION OF THE OVARIES OF FULLY ENGORGED ADULTS.

Thirty-one fully engorged (++++) adults were taken from time to time and successfully dissected. They lived from 30 minutes to 67½ hours. Six specimens contained ovaries corresponding to stage 1. These lived from 30 minutes to 4 hours 35 minutes. Two adults, which lived 17 and 24 hours, respectively, contained ovaries with the eggs between stages 2 and 3. Six specimens contained ovaries with eggs typical of stage 3 in large numbers. These lived from 18 to

28½ hours. One specimen which lived 23½ hours contained ovaries with only a small number of eggs, about 25 in each ovary. One adult which lived for 44 hours contained ovaries between the third and fourth stages, and showed the transition from stage 3 to stage 4 very clearly. Twelve adults contained ovaries filled with fully developed eggs (stage 4, Pl. I, fig. 4), ranging in number from 200 to 300. These adults lived from 30 to 67½ hours. Two adults contained ovaries with eggs of stage 4, but in small numbers, about 50 in each ovary. They lived 48 and 56 hours, respectively, and possibly had developed the remainder of the eggs left within the ovary after a previous oviposition. One adult contained ovaries with eight fully developed eggs, and the remainder of the ovary filled with eggs corresponding to stage 3. This adult lived 34 hours and had presumably oviposited once, as is indicated by the presence of the eight fully developed eggs, and then developed the remainder of the ovaries to stage 3.

A comparative study of the ovaries of well-engorged (+++) specimens shows that no adult which died before reaching a period of longevity of 30 hours after engorgement developed the eggs within the ovaries to full degree. On the other hand, with one exception, all adults which lived for 30 hours after engorgement developed the eggs within the ovaries to the fullest extent. The fully developed eggs within the ovaries were of the same shape as eggs freshly laid, and only a fraction smaller.

THE APPARENT EFFECT OF A BLOOD MEAL UPON THE DEVELOPMENT OF THE OVARIES.

In the studies which have been made of the ovaries of females of *Simulium venustum* under various conditions the following points are worthy of emphasis: (*a*) In all adults taken while ovipositing, apparently digested blood was found in the stomach. (*b*) No eggs within the ovaries developed to the fullest degree without engorgement and the requisite time in which to digest the blood meal. (*c*) The condition designated as stage 5 occurred both in adults which had just oviposited and also in adults which were taken on animals and killed at the time of capture. This condition (stage 5) seems to furnish strong evidence that adults feed again after ovipositing, as the majority of engorged adults showed the entire contents of the ovaries developed. In addition the exact cause of the similar condition found in adults which had just oviposited is known; namely, that a few fully developed eggs were left in the ovaries after oviposition and the remainder of the eggs were in a rudimentary condition apparently awaiting the necessary factors for development. (*d*) The males have reduced mouth parts and are not found engorging on blood, indicating the acquisition of this habit by the females for a special purpose, as is the case with other blood-sucking Diptera.

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DIV. INSECTS

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 333

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER February 16, 1916

TERMITES, OR "WHITE ANTS," IN THE UNITED STATES: THEIR DAMAGE, AND METHODS OF PREVENTION

By

THOMAS E. SNYDER, M. F., Assistant in Forest Entomology, Forest Insect Investigations

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TERMITES, OR "WHITE ANTS," IN THE UNITED STATES: THEIR DAMAGE, AND METHODS OF PREVENTION.[1]

By Thomas E. Snyder, M. F.,
Assistant in Forest Entomology, Forest Insect Investigations.

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INTRODUCTION.

Termites, or "white ants," which are classed among the most injurious insects to man's industry in tropical regions, are by no means restricted to the Tropics and in the United States are capable of seriously damaging the woodwork as well as the contents of buildings and other structures of wood, and occasionally the roots of living trees and various growing crops. In the United States these insects more frequently occur and more often become a pest in the Southern States. Due to their subterranean habits, insidious method of attack, and often countless numbers, termites are very difficult to destroy. Always coming up through underground galleries, they work under cover, avoiding exposure to the light, so that the damage is often hidden until beyond repair.

CLASSIFICATION.

"White ants" are not ants, but, because of their superficial resemblance to ants (except in color) and their communal habits, they have been almost universally so termed. Thus these insects, since they live

[1] The species principally treated herein are *Leucotermes flavipes* Kollar, *L. virginicus* Banks, and *L. lucifugus* Rossi.

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in colonies which are made up of various highly specialized forms or castes, are naturally to be classed among the so-called social insects, comprising the ants, bees, and wasps. Each of these forms has a duty in this organization and there is a division of labor. In the systematic classification of insects, however, termites are widely separated from the other social insects, which represent the highest and most specialized development, while termites are among the lowest and oldest insects. Further, in many points in their life habits termites differ widely from the other social insects.

DESCRIPTION OF THE INSECTS.

THE DIFFERENT FORMS OR CASTES IN THE COLONY.

Since the work of termites is largely subterranean, or under cover, the insects are rarely observed at work and the injury is often hidden

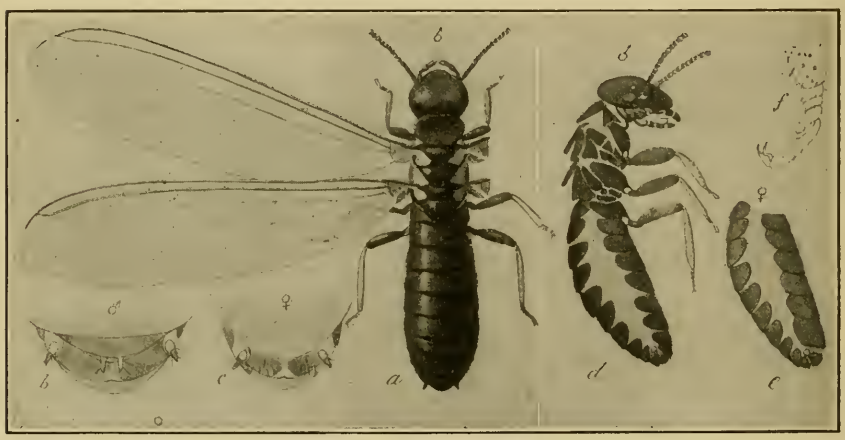


FIG. 1.—*Leucotermes flavipes: a,* Adult male; *b,* terminal abdominal segments from below; *c,* same of female; *d,* male, side view, somewhat inflated by treatment with ammonia; *e,* abdomen of female, side view; *f,* tarsus, showing joints and claws. *a, d, e,* Enlarged; *b, c, f,* greatly enlarged. (After Marlatt.)

until the destruction of the wood that they are inhabiting is complete. An indication of the presence of termites is the annual flight or swarm of the winged colonizing sexed adults which emerge in enormous numbers from the ground and crevices or holes in infested wood.

In the communal societies of termites, however, there are both wingless and winged mature individuals, as well as the young of the different forms in various stages of development. The brownish or blackish, elongate, slender, antlike adults (fig. 1) with long white wings are not the most destructive form, although they have biting mouthparts, but are migratory individuals which have the sexual organs developed, and appear normally only once a year during a certain season, which varies with the species. These male and female

reproductive forms have functional eyes, and, unlike the other forms, are especially adapted to endure full sunlight, since it is necessary that they come above ground to found new colonies, possibly because of a superabundance of life in the old, parent colony, or in order that the species may become more widely disseminated.

The dirty-white, soft-bodied, large-headed, wingless "workers" (Pl. I, fig. 1) comprise the most destructive form. These "workers" have varied and important duties; they make the excavations, enlarge and extend the colony as this becomes necessary, and care for and protect the young and reproductive forms. The soft-bodied, wingless "soldiers" (Pl. I, fig. 2), which have an elongate narrow head armed with long, slender, saber-shaped jaws, and the workers are the most numerous forms permanently present in the colony. The duty of the specially developed soldiers is apparently protective. Both the workers and soldiers consist of individuals of either sex, but the sexual organs remain undeveloped. The integument of the body of these insects is delicate and the chitinous plates are never very hard. These forms are blind and rarely appear above ground; hence in all their operations they carefully shun the light, which they nevertheless are apparently able to detect. Other forms are the reproductive individuals, which may be either a single pair, the normal king and queen (Pl. II, figs. 1 and 2), or in other colonies many supplementary forms of nymphal types (Pl. II, figs. 3 and 4; text fig. 4, *b*) or larval types (fig. 3; fig. 4, *c*).

THE DIFFERENT SPECIES OF TERMITES.

Of the many different species of termites in North America, the habits of only three are here considered in detail, namely, the common native termite (*Leucotermes flavipes* Kollar), a European termite (*Leucotermes lucifugus* Rossi), and the native southern species (*Leucotermes virginicus* Banks). These termites are greatly similar in form and habit and are all wood-destroying species of subterranean habits, with a relatively northern distribution. The winged sexed adults have strongly reticulated wings.[1]

In case of *flavipes* ("yellow foot"), these adults are clear castaneous-brown, 9 to 10 mm.[2] in length, including the wings, which are dull white in color, or plainly darkened, the borders being clear brownish, except at the base. The simple eyes or ocelli are separated from the faceted compound eyes by the width of their diameter. The swarm is usually in April or May. The soldiers are 6 to 7 mm. in length, the head being about once and two-thirds as long as broad.

In *lucifugus* ("light shunning"), the winged adults are dark blackish-brown, 11 to 12 mm. in length including the wings, the latter being dull smoky blackish with the borders black-brown. The ocelli are nearer to the compound eyes. This species swarms from October to April.

The southern smaller species (*virginicus*) is yellowish brown in color, being 7.5 to 8 mm. in length, including the wings, which are not darkened. The

[1] Subgenus *Reticulitermes* Holmgren.

[2] 1 mm.=one twenty-fifth inch.

swarm is usually in early June or later in the summer. The soldier is more slender than in *flavipes*, 4.5 to 5 mm. in length, the head being twice as long as broad.

In certain localities where several species of termites are known to occur the injury herein described can not always be attributed to a definite species, since specimens of the insects were sometimes not taken. This is particularly the case in the Southwestern and Gulf States and on the Pacific coast. It is probable that species not previously recorded as injurious will be found to be injurious, and it is known that undescribed species or those new to science occur.

COMMUNAL ORGANIZATION AND LIFE.

SITUATION OF THE COLONIES OR NESTS.

In North America termites do not construct large permanent nests of earth or mounds above ground, as in the Tropics. They make the nests in the wood of dead trees, decaying logs, or stumps in the forest; or in the foundation timbers of buildings, fences, or other structures of wood in contact with the ground; or in a labyrinth of underground passages in the earth, usually underneath wood or other vegetation. These nests are not as permanent as the mound nests, since the species have wandering habits and there are seasonal changes in the colony life. These species of termites (*Leucotermes* spp.) are essentially wood destroyers; their excavations usually follow the grain in solid wood. A protective outer shell of wood is always left intact by these blind, soft-bodied insects. Termites infest buildings by means of tunnels through the ground to and up through the foundation timbers, or, in case of foundations of stone or other impenetrable material, cover their pathway by means of "sheds" constructed of earth and excrement over the surface to the woodwork. Termites sometimes inhabit and enlarge the burrows of various other wood-boring insects.

SEASONAL VARIATIONS IN THE COLONY.

The center of activity in termite colonies changes with the seasons, due to varying needs as to conditions of warmth and moisture. In the eastern United States, in spring, when there is abundant moisture, outlying galleries of colonies are teeming with life, where, during the heat of summer, conditions would be too dry. In arid regions termites burrow deep into the ground; consequently in summer they bury themselves more deeply, going into the less exposed galleries. In the late autumn or at the beginning of winter (in northern Virginia, late October or early November) they enter the ground and do not come above ground till late in February or early March. Again, the colony readily migrates and the site is abandoned if conditions

FIG. 1.—Mature "workers" of *Leucotermes flavipes;* chloroformed, living insects. Enlarged three times. (Original.)

FIG. 2.—Mature "soldiers" of *Leucotermes flavipes;* chloroformed, living insects. Enlarged three times. (Original.)

TERMITES, WORKERS AND SOLDIERS.

FIG. 1.—Mature "king" of normal form, several years of age. Etherized specimen, enlarged six times. (Original.)

FIG. 2.—True "queen" with wing stubs and castaneous pigmentation to chitinized parts. Enlarged six times. (Original.)

FIG. 3.—Neoteinic nymphal "king" showing tapering abdomen and characteristic pubescence. Enlarged seven times. Alcoholic specimen. (Original.)

FIG. 4.—Neoteinic nymphal "queen" with straw-colored pigmentation to chitinized parts. Enlarged seven times. (Original.)

REPRODUCTIVE FORMS OF TERMITES.

become unfavorable. A single colony may be spread over an extensive area, and it is often impossible to define the limits of a colony. At higher altitudes in the Appalachian Mountains, in the canyons of the Southwest, and in high mountains in the West, termite colonies in the earth and under stones are more common. Colonies of Eutermes are commonly found in the earth.

NUMBER OF INDIVIDUALS IN COLONIES.

Average colonies probably contain several thousand individuals. In old, long-established termite colonies the number of individuals runs up into the tens of thousands. Young, recently established or incipient colonies are small and the increase in numbers is slow.

THE LIFE CYCLE.

THE METAMORPHOSIS AND CASTE DIFFERENTIATION.

The recently hatched termite larvæ (fig. 2) are all similar or undifferentiated, but are active from the first. At a later molt two types, large and small headed larvæ, can be distinguished. The former, after a series of molts and quiescent stages of comparatively short duration, develop to workers and soldiers, the latter to reproductive forms.

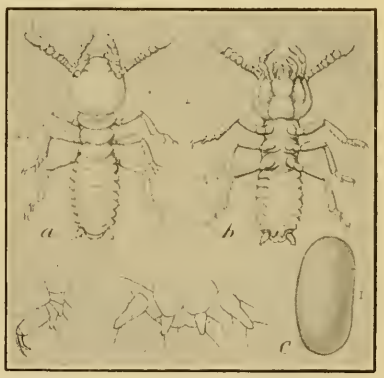


FIG. 2.—*Leucotermes flavipes: a,* Newly hatched larva; *b,* same from below; *c,* egg. All enlarged. (From Marlatt.)

There is no apparent or external change in the development of the worker, the larva being active and of the same form as the adult. There are marked changes, however, in the development of the soldier, with narrow, elongate head and saberlike jaws, from the round-headed, worker-like larva. The winged, pigmented, sexed adults and the several types of neoteinic reproductive forms are developed from small-headed larvæ, there being still more radical changes, the former originating from nymphs of the "first form," with long wing pads, the latter from nymphs of the "second form" (Lespès) with short wing pads, or from young larvæ.

However, in all stages of the development of termites, what may be termed the "antlike" form of all castes can be recognized. There are no long inactive larval and pupal stages as in the ants and other social insects.

In the life cycle of termites there is so much variation in the development of the castes that there is consequently a rather complex

life history. Young are kept in a retarded, undifferentiated state and can be rapidly turned into supplementary or substitute reproductive forms of both sexes.

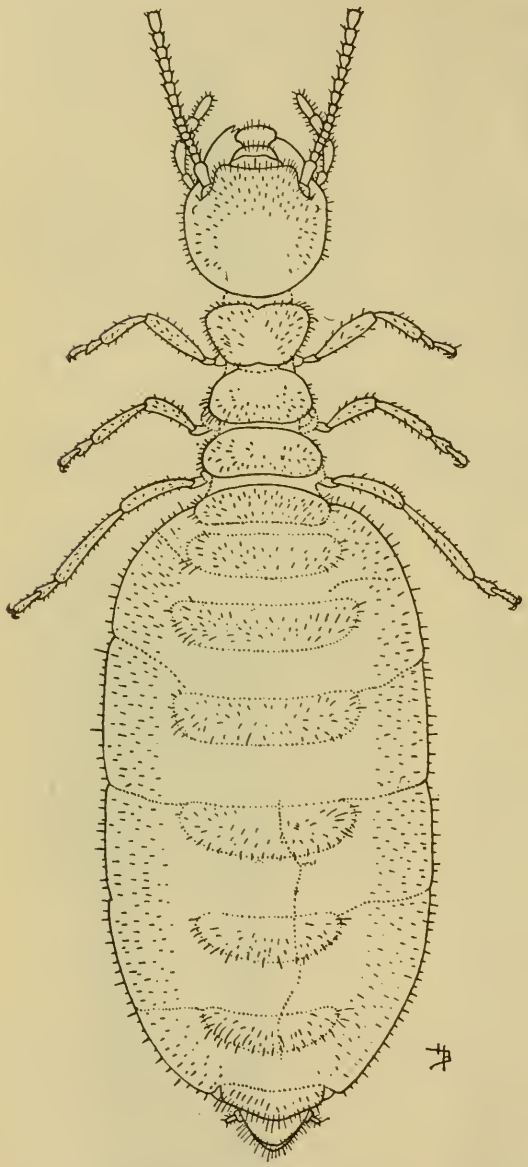


FIG. 3.—*Leucotermes flavipes:* Larval, worker-like reproductive form ("ergatoid queen," 9 mm. in length, alcoholic specimen). (Original.)

THE SEVERAL TYPES OF REPRODUCTIVE FORMS.

The nymphs of the first form, with long wing pads, develop to the winged sexed adults, which, after the swarm, lose the wings and become the kings and queens of the normal reproductive form. These normal kings and queens are blackish or brown in color, have eyes, and retain the stumps of their discarded wings (fig. 4, *a*).

From the nymphs of the second form, with short wing pads, are developed, probably by the workers, individuals of the substitute nymphal reproductive form of both sexes (Pl. II, figs. 3 and 4; text fig. 4, *b*). These nymphs of the second form are merely nymphs of the first form whose usual development to the pigmented, winged, sexed adults is retarded at a certain stage and never completed; the insects, instead, acquiring a pale yellowish or grayish color and becoming sexually mature normally after the sexed adults have swarmed. Individuals of this neoteinic reproductive form are apparently blind, not being destined to leave the parent colony, unless by underground tunnels.

Another type of substitute or neoteinic reproductive form, which greatly resembles the worker ("ergatoid"), is developed from young larvæ of the sexed forms. Of a pale yellowish or grayish color and having no wing pads (fig. 3; fig. 4, *c*), individuals of this larval supplementary reproductive form are apparently blind and never leave the parent colony, unless by underground tunnels.

In neither of the types of supplementary reproductive forms do the queens become as large as the normal queens, but there are usually many present in the same colony, as well as several males, or kings. The largest queen found in the United States of *L. flavipes* Kol. is only 14½ mm. in length and 4 mm. in width (measured while liv-

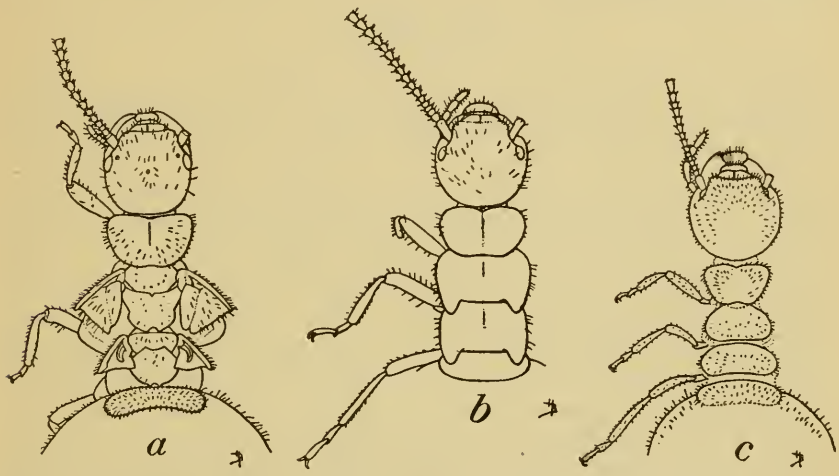


FIG. 4.—*Leucotermes flavipes:* Details of head and thorax of the three forms of reproductive females. *a*, True queen, or adult form, 14.5 mm. in length, wing stubs present; *b*, supplementary or "neoteinic" queen, or nymphal form, 9 mm. in length, wing pads present; *c*, worker-like or "ergatoid" queen, or larval form, 9 mm. in length, without wing pads. (Original.)

ing)—a queen of the normal type with wing stubs. Nymphal neoteinic queens 12 mm. in length (alcoholic specimens) and larval neoteinic queens 7 mm. in length (measured while living) are the largest that have been found of this species. The abdomens of nymphal queens are often distorted by the development of the ovaries and present an irregular, lopsided outline. These neoteinic forms of both sexes are probably developed to take the place of the normal forms in case of loss or possibly in the establishment of branch colonies; i. e., they may be impelled to migrate from overstocked colonies by means of underground passages. Queens of all these different types of reproductive forms are active even after the abdomen has become greatly distended.

DURATION OF DEVELOPMENT AND LIFE.

The workers, like the soldiers, complete their development in less than a year. The development of the nymphs of the reproductive forms (coming from larvæ that will mature the sexual organs) apparently requires two seasons.

For the development of the queen of the normal type to the maximum size several years are required.

There are no data on the length of life of individuals of the various castes, but the king and queen probably continue to live together for many years, under normal conditions, since they are of equal importance to the community.

THE SWARM.

At a certain season of the year the colonizing, winged, sexed individuals are impelled to migrate from the parent colonies in decaying logs, stumps, woodwork in buildings, etc. In case of the widely distributed species *flavipes*, the colonizing forms emerge from colonies in April or early in May in the Southern States or the last of May or early June in the Northern States; the swarm usually occurs in the morning or in the middle of the day, in case of large colonies usually lasting about two hours. The southern species *virginicus* swarms in early June, but sometimes as late as the first part of August in northern Virginia; while the species *lucifugus* of Mediterranean Europe swarms from the middle of October to April in Texas, Kansas, Colorado, and on the Pacific coast, usually after showers. Often several swarms occur from the same colony, extending over a period of four weeks. In colonies in infested buildings the winged males and females usually emerge about one month before the swarm occurs outdoors.

THE FOUNDATION OF NEW COLONIES.

After the adults have rapidly emerged from the parent colony, from crevices in the infested wood, in a swarm of enormous numbers and have flown a short distance in an irregular, "wobbly" manner, they fall to the ground. The flight is usually not farther than from 75 to 100 feet, but the insects, usually flying low, are sometimes carried farther by the wind. Both during and after the flight they are promptly preyed upon and destroyed by many insectivorous animals which are attracted to the cloud of flying insects, resulting in an enormous mortality.

Among these enemies are many species of wild birds which are attracted to swarms of termites in woodland and greedily capture the flying insects in midair.

Hagen states,[1] in mentioning an exceptionally large swarm which occurred in Massachusetts:

> Last Sunday, May 19 (1878), on North Avenue, near Everett Street, there passed just before the windows of the house of Prof. Hedge, while the family was at breakfast, a cloud of flying insects, dark enough to draw the attention of the family. They went out of doors and saw the cloud coming from the east, a part alighting on the garden steps. Some of the insects were preserved alive and sent to me, and proved to be *Leucotermes* (*Termes*) *flavipes*.
>
> The phenomenon was more remarkable, and their attention more strongly called to it, by finding 15 different kinds of birds following the insects so eagerly that even the presence of the family did not disturb them. Besides the common robbins, bluebirds, and sparrows, were others not seen before near the house. The birds caught the Termes partly in flight, partly on the ground, and the robins were finally so gorged in appearance that their bills stood open.
>
> I think such a flock of birds following an emigration of white ants—which is very common in the Tropics—has never been noticed here. Perhaps the very early appearance of white ants (commonly they arrive in the middle of June) explains the hunger and eager persecution of the birds, as other insects are still rare.

The Biological Survey has found that termites constitute part of the food of at least 27 of the species of birds living in the United States. The woodpeckers are represented in this list by 8 species, and no fewer than 1,100 termites have been found in a single stomach of the common flicker. Other birds consuming noteworthy numbers of termites are the nighthawk (largest number found in one stomach, 220), chimney swift (160), tree swallow (75), barn swallow (50), and bank swallow (50). The complete list of birds is as follows: Wood duck, hairy woodpecker, downy woodpecker, red-cockaded woodpecker, Nuttall's woodpecker, pileated woodpecker, flicker, red-shafted flicker, gilded flicker, nighthawk, chimney swift, kingbird, Cassin's kingbird, black phœbe, western wood-pewee, horned lark, meadowlark, song sparrow, scarlet tanager, barn swallow, tree swallow, bank swallow, mockingbird, catbird, Carolina wren, wood thrush, and bluebird.

Barnyard fowls also are attracted to the swarming insects and capture large quantities of the insects as they emerge. Lizards (in California and in southeastern Texas) have been observed to devour swarming termites. Many different species of spiders also prey on the insects after they alight on the ground. Among the insects, ants[2] greatly diminish the number of the colonizing individuals at the time of the annual swarm. Centipedes have been observed in Virginia to carry away in their mandibles workers from a disorganized colony; they are sometimes found in the covered earthen runways of termites. Crickets[3] have been recorded feeding

[1] Hagen, H. A. Note.—*In* Proc. Soc. Nat. Hist. Boston, v. 20, p. 118, Nov. 27, 1878.
[2] Species of *Cremastogaster, Camponotus,* and *Formica.*
[3] *Gryllus pennsylvanicus* Burm.

on swarming adults (*lucifugus*) in Kansas (McCulloch). Probably there are many other insectivorous animals that reduce the enormous number of winged termites.

While clumsy in flight, termites are able to run rapidly, but apparently never wander great distances. Further, even some of those pairs that escape being devoured fail to become established in new colonies because of unfavorable moisture conditions in the incipient colony.

The male is attracted to the female, and after the flight, either before or after the now useless and retarding wings have been discarded by being pried off at a suture near the base, tirelessly and closely follows her about. In this manner the insects separate into pairs and become established in shallow cells in the earth, usually under decaying pieces of wood, in holes in the wood, or under moist bark, thus independently establishing new colonies.

The female in seeking the site of the new colony is sometimes followed by more than one male, and in shallow cells excavated by these reproductive forms there may be one female associated with two males or vice versa.

MATING.

During the first stages of colonization both the male and female are active, forage for themselves, and are apparently equally important in the establishment of the new colony and the independent rearing of the first brood of young.

The habitation of the male and female or incipient colony is called the "royal cell," since it is occupied by a single parent pair, the especially developed "king and queen," which have originated from the winged, sexed adults after the swarm. The first brood is reared within the confines of this small chamber. In this type of reproductive form, after the pair have become established together, there is further sexual development and the abdomens of both sexes increase slightly in size. In case of the queen there is a later considerable post-adult growth.

Unlike the other social insects, the sexual relations of the male and female termite are continued. Copulation probably does not take place until about one week after the swarm and the establishment of the pair in the royal cell, but is repeated at irregular intervals over a period of many years.

THE RATE OF EGG LAYING.

Egg laying in newly established colonies in case of the species *flavipes*, in the southeastern United States, begins about the middle of June or July; and in late June to July, or August—unhatched eggs being present till the middle of August—in incipient colonies of

virginicus, varying with the season, or about one and one-half months after the swarming. Usually only 6 to 12 eggs compose the first batch; they are deposited in a cluster in the royal cell and are carefully tended. The eggs begin to hatch in about 10 days after they are laid.

Most larvæ of the first brood develop to workers and a few to soldiers. While the recently hatched young are active they are dependent on the care of the parents for food. During the development of the first brood the male continues to share the cell with the female and both are active. The abdomen of the queen at this time is not markedly distended. Egg laying ceases after the first batch is laid and is not resumed until the first brood of young is mature, i. e., about six months after the first eggs were laid. Copulation and egg laying occur at shorter intervals and more frequently from now on and the abdomen of the queen gradually enlarges, eventually becoming greatly distended through constant care and feeding by the workers and the enormous development of the ovaries. These queens never reach the size attained by species in the Tropics.

The rate of egg laying and development of the young and active queen of this normal type is slow and the new colony is small. Even after the rearing of the first brood the increase in numbers is not rapid. The capacity for egg laying becomes gradually increased as the abdomen enlarges, but queens of these species (*Leucotermes*) never entirely lose the power of locomotion. An isolated, fully developed queen of *flavipes* (approximately 14 mm. in length) was capable of laying, after capture, over 1 dozen eggs between 5 p. m. and 9 a. m. Hence even in large, well-established colonies the rate of egg laying of normal queens is not remarkable. However, where there are many neoteinic reproductive forms of both sexes in colonies the increase is rapid and extensive. The rate of egg laying is not comparable to that in tropical species.

Since no types of the reproductive forms ever entirely lose the power of locomotion, there is, in consequence, no permanent royal cell, but these forms are usually in a cell in the more solid wood. In winter they probably are to be found below the frost line in the ground, where termites pass the cold season in a labyrinth of galleries. Wood-boring ants[1] are to be found in frozen masses in galleries in wood, but the soft-bodied termites pass the winter below ground in a state of sluggish activity or are more or less dormant.

THE PERIOD OF MAXIMUM EGG PRODUCTION.

In large, long-established colonies of *flavipes* in the eastern United States eggs and newly hatched larvæ (fig. 2) are to be found

[1] *Cremastogaster* sp. and *Camponotus* sp.

from April to October; in incipient colonies of *flavipes* in northern Virginia the first eggs are laid by the middle of June or July, or from the last of June to July or August in case of *virginicus*.

In northern Virginia, in well-established colonies, the period of maximum egg production of both species is from the middle of May to early September; that is, during the warm months.

In infested buildings occupied by man termites are able to maintain their activity during the entire year, and it is probable that eggs are produced in every month of the year.

The eggs are tended by the young parent adults in the royal cell in incipient colonies, but in long-established colonies the eggs are removed by the workers and deposited in clusters in the outlying galleries of the colony where conditions are best suited for rapid hatching.

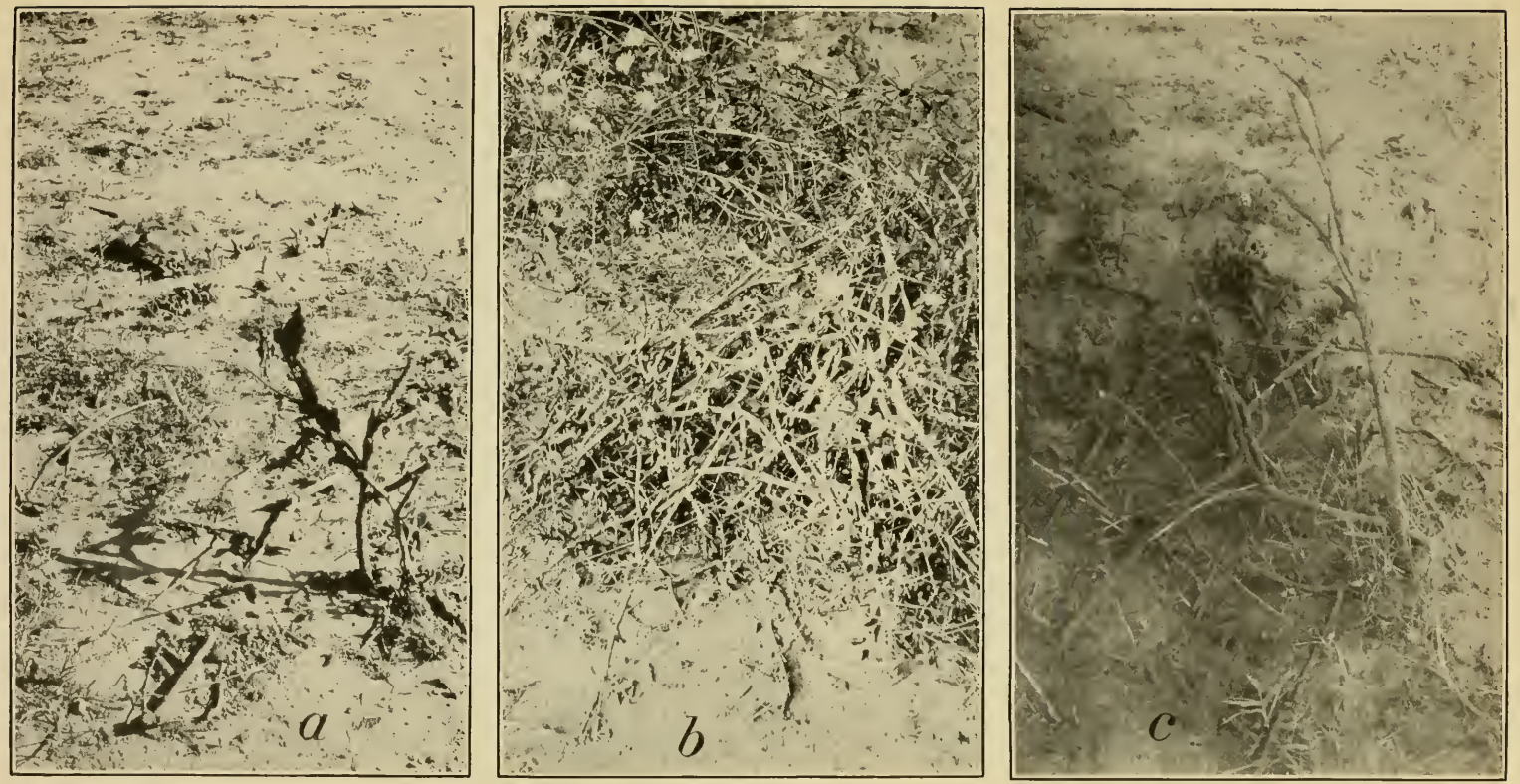
GEOGRAPHICAL DISTRIBUTION.

Termites are widely distributed over the world, but increase in numbers as the Tropics are approached. There are many species in North America. Our common species *flavipes*, according to Marlatt, is very widespread over North America, "occurring from the Atlantic to the Pacific and from Canada southward to the Gulf. It has been found on the mountains of Colorado and Washington at a height of over 7,000 feet." This termite has been introduced into Europe, being also reported to occur in Japan. S. Hozawa states[1] that *Leucotermes spretus* Kolbe is the only representative of the genus *Leucotermes* in Japan, and that *L. flavipes* has not been found in Japan. Another termite closely allied to *flavipes*, *lucifugus*, occurring in the Mediterranean countries of Europe and also in western France and Hungary, but being especially abundant throughout southeastern Europe, according to E. A. Schwarz, originated in Mexico. This insect has also been introduced into North America (western United States). In the United States *lucifugus* is found in Texas, Arizona, Kansas, Colorado, and southern California, and proably occurs elsewhere. This species also occurs at high altitudes in Colorado, i. e., about 6,000 feet. The native species *virginicus* is recorded from the District of Columbia, Maryland, and Virginia, but probably has a wider distribution.

In the prairie regions of Texas and Arizona a tube-forming termite[2] lives in the ground, in pasture tracts, feeding on the roots of grass and other vegetation, often being found under and within dry cow dung and under stones. A characteristic habit of this grass-destroying species is to cover the stems and roots of vegetation with

[1] Jour. of the College of Science, Tokyo Imperial Univ., v. 35, art. 7, p. 82, Apr. 30, 1915, "Revision of the Japanese Termites."

[2] *Hamitermes tubiformans* Buckley.



TERMITE SHELTER TUBES.

Stems of both living and dead vegetation incrusted with earthen tubes of the termite, *Hamitermes tubiformans*. Esperanza Ranch, Brownsville, Tex., June 12, 1904. Photographs by H. S. Barber. (Original.)

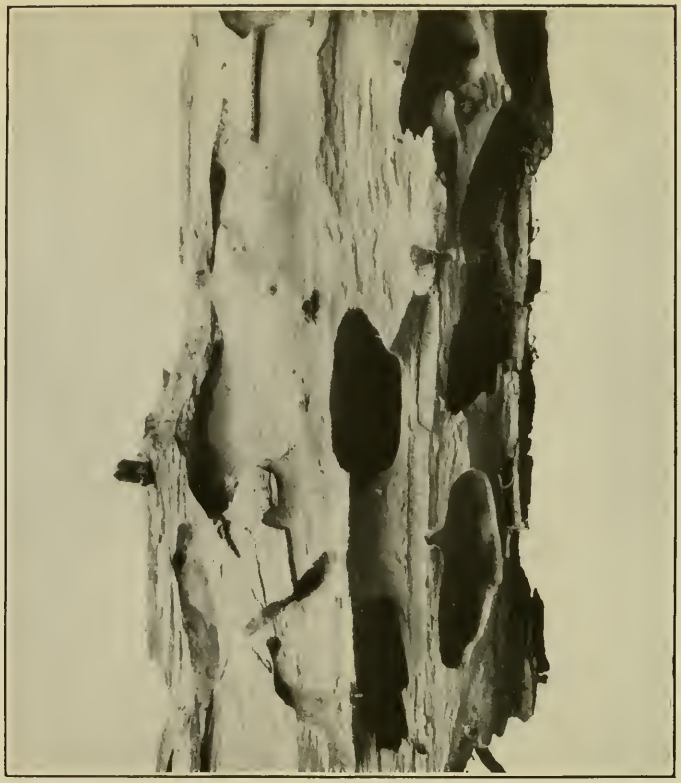


FIG. 1.—Chambers excavated in Arizona cypress (*Cupressus arizonica*) by *Calotermes* sp. Catalina Mountains, Ariz. (Original.)

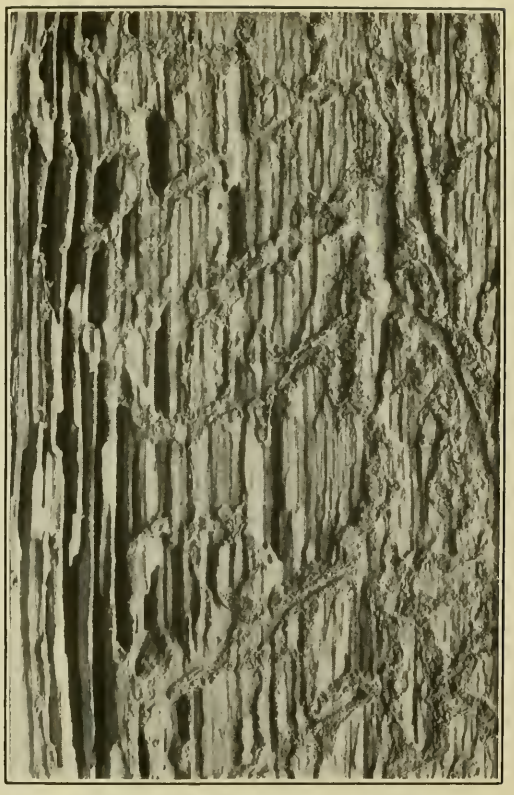


FIG. 2.—Damage by termites (*Leucotermes* sp.) to sound dry red-oak molding from door casing, showing walls of runways coated with earth mixed with finely digested excreted wood. (Original.)

tubes of small diameter, constructed of earth and excrement (Pl. III). M. Chrisman has found these termites in Arizona under similar coverings at the base of mesquite stumps, fallen limbs, twigs, etc.; always on the dry wood, but not in cells in the wood, apparently eating only the outside. Many other termites occur in North and Central America.

ECONOMIC IMPORTANCE OF TERMITES IN THE UNITED STATES.

While termites damage a great variety of wooden structures, stored books, documents, paper, and other material, as well as occasionally injuring or killing living trees, shrubs, and growing crops, the principal and most serious damage is to foundation timbers and the woodwork of buildings occupied by man and the contents or material stored therein. Similar damage to other construction timber in contact with the ground is considerable in the Southern States. Apparently, it is only occasionally that these insects attack living trees and shrubs, growing crops, or other vegetation, and then only because the land has been recently cleared and there is much decaying wood or humus in the soil; or, according to C. L. Marlatt, of the Bureau of Entomology, in the case of corn in the prairie region of Kansas, because the insects are present in enormous numbers and have been breeding in the heavily sodded soil, where they feed on the roots of the vegetation. Sometimes this injury to growing corn is due also to the method of plowing under old stubble.

Hence, in the following account of general damage to a great variety of stored material and products, as well as living crops, it should be borne in mind that such damage is usually occasional, and then only local and not in general a serious problem.

DAMAGE TO BUILDINGS AND OTHER STRUCTURES OF WOOD.

Damage to foundation timbers, flooring in basements, and other woodwork of dwellings occupied by man, as well as to other buildings, is common and occasionally serious in the eastern and southern portions of the United States, especially in the South Atlantic and Gulf States. Injury of this type has been recorded as occurring in large cities,[1] as well as in rural regions, as far north as Manchester, N. H., and the shores of the Great Lakes (Benton Harbor, Mich.).

[1] Records in the correspondence files of the Bureau of Entomology and branch of Forest Insect Investigations include Benton Harbor, Mich., Manchester, N. H., Boston, Mass., New York, N. Y., Atlantic City, N. J., Philadelphia, Pa., Wilmington, Del., Baltimore, Md., Washington, D. C., Wheeling, W. Va., Cleveland, Cincinnati, and Dayton, Ohio, Indianapolis, Jeffersonville, and South Bend, Ind., Cazenovia, Ill., St. Louis, Mo., Charlotte, N. C., Charleston and Spartanburg, S. C., Louisville and Franklin, Ky., Memphis, Tenn., Augusta and Savannah, Ga., Montgomery and Birmingham, Ala., Vicksburg, Miss., Jacksonville, Miami, and St. Augustine, Fla., New Orleans and New Iberia, La., Beaumont, Dallas, and San Diego, Tex., Little Rock and Van Buren, Ark., Oklahoma City and Wewoka, Okla., Manhattan, Kans., Colorado Springs, Colo., Salt Lake City, Utah, and localities in southern California.

W. D. Hunter stated on November 6, 1915: "The recent hurricane injured practically every building in the city [New Orleans, La.] more or less, and hundreds were completely demolished. * * * Many of the exposed beams were mined by insects and in many cases at least this weakening of the timbers was an important contributory cause of the loss." Much of this damage was probably due to termites.

Termites usually gain entrance to buildings from colonies outdoors, and since the workers can extend subterranean galleries for comparatively long distances, it is often impossible to trace the insects to the outside source. However, these galleries, constructed in search of moist or decaying wood, originate in decaying stumps, poles, fence posts, boards, or other decaying wood, or in the earth not very far away.

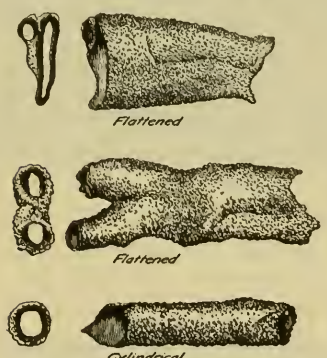


FIG. 5.—Suspended tubes constructed by termites (*Leucotermes flavipes*) of earth and excreted wood, Elkins, Va. Natural size. Drawn by Miss E. Hart. (Author's illustration.)

By means of these subterranean tunnels infestation by way of wooden beams, joists, or supports of porching or steps in contact with the ground is effected. Termites can even pass over impenetrable surfaces, such as stone, brick, or concrete foundations, by means of small sheds or tubes constructed of earth and excrement on such surfaces or by means of suspended tubes (fig. 5). Sometimes ingress is gained through cracks in concrete where foundation timbers are imbedded in this material. These insects have even been recorded by Forbes as boring several feet through the mortar or cement between the stones in foundation walls and brick partitions of the Statehouse at Springfield, Ill., and by Grant as perforating the mortar of the brick walls of a Missouri Pacific Railroad engine house (probably through cracks or where the cement was disintegrated). There are several records of termites piercing the lead covering to telephone cables in Australia and the United States (Savannah, Ga.).

Since their work is hidden, the presence of termites is often not discovered till the damage is beyond repair. Thus beams, flooring (Pl. XV, p. 28), walls and other woodwork, even up to the second and third floors, and furniture are reduced to mere outer shells, the interior being completely honeycombed; often these intervening longitudinal layers of wood that are left uneaten are reduced to the thinness and consistency of paper. Sometimes the settling of floors or the collapse of joists is the first indication that the building is infested. This often necessitates extensive repairing or complete rebuilding after tearing down and removing the infested timber.

However, the annual emergence of the winged adult termites is an indication of infestation and the point of emergence shows the approximate location of the infested timber. The presence of the earthlike tubes on timber or rock foundations of buildings is also a warning that the building is infested by termites.

While injury by termites in tropical regions affects not only the soundness of the building,[1] but the dry, hard wood of furniture and other contents as well, in this country attack is usually begun in moist or decaying foundation timbers. However, termites are able to extend their burrows throughout dry, hard wood and other dry substances, provided that there is access to moisture elsewhere; i. e., they make use of a mixture of moist frass and earth in creating more favorable conditions. Thus there is, in infested buildings, occasional damage to flooring, wooden partition walls, wainscoting, molding, door casing (Pl. IV, fig. 2), sills, window and door frames, wooden lath and wall plaster,[2] as well as to tiling o rother interior construction made of wood pulp (Pl. V), furniture, wall paper, starched cotton curtains, and various stored material.

In infested buildings, where they have worked for several years, the insects having usually entered the house by means of joists or stringers in contact with the ground or set in concrete, work is begun in the flooring next to the walls, and burrows are excavated in toward the center of the room. The woodwork of coal bins in cellars sometimes becomes infested and is the cause of the insects gaining entrance to the flooring and other woodwork of the building.

Flooring, other woodwork, and furniture in infested buildings above boilers or furnaces where the temperature is high or the wood is moistened by hot steam are especially liable to attack.

In addition to the private residences, hotels, and business houses occupied by man, termites infest factories, granaries, barns, greenhouses, sheds, outhouses, and other wooden structures. The framework of wooden greenhouses, which are always warm and moist, is especially liable to attack and may be seriously damaged. The injury in these structures is extended to the wooden plant benches, plant tubs, label sticks, and sometimes to the growing plants.

Many other structures of wood are damaged by termites, any timber in contact with the ground being especially liable to attack.

[1] *Calotermes marginipennis* Latr., recorded from Central America (Mexico and Panama) and California, is especially injurious to the woodwork of buildings and other structures, and such injury in the Southwestern States and in California may be due to this or closely allied species of Calotermes. This species excavates chambers in the interior of the solid wood, rather than honeycombing it as do species of Leucotermes. (Pl. IV, fig. 1.) An indication of the infestation by Calotermes is the small oval sculptured pellets of excrement expelled by the insects. There is a record of damage to painted dry siding of a railroad business car at Los Angeles, Cal., by Calotermes, Apr. 6, 1915, and to the pine sill of a porch at Palm Beach, Fla., May 4, 1915, by *Cryptotermes cavifrons* Banks.

[2] In Baltimore, Md., and in Charlotte, N. C., the plaster laid on wood and patent metal lathing was probably only incidentally bored to allow the colonizing sexed adults to emerge at the time of the annual swarm.

Among these may be listed construction timber in bridges—there are only two actually recorded cases, one near Cambridge, Mass. (H. A. Hagen), and the other near Cleveland, Ohio (F. L. Odenbach)—wharves, and like structures; telephone and telegraph poles and poles used by electrical and other companies (in New York, New Jersey, Pennsylvania, West Virginia, southern Illinois, Indiana and Ohio, Missouri, Nebraska, California,[1] and in general the Southern States[2]); hop and bean poles; mine props and other timbers on the slope of incline mines (in West Virginia and Alabama); posts, lower rails, and boarding of fences; lumber piled on the ground; crossties (New Jersey, Virginia, Maryland, and the Southern States); improperly creosoted wood paving blocks (used as flooring in a factory building in Atlanta, Ga.; the wooden boxing or conduits of cables in the ground, to the detriment of the insulation; the woodwork in wells; wooden silo tanks; the ridge poles of tents, and tent pins (in desert near Boise, Idaho); wooden tree boxes; wooden beehives (near Shelbyville, Tenn.), the last being infested through wooden crosspieces lying on the ground.

According to F. H. Chittenden much injury is done by white ants (*lucifugus*) in hopyards. The dead roots, trellis poles made of redwood, and pine string pegs are attacked in California.

There is evidence that termites not only injure man's habitations while alive, but also infest the last resting place of man on this earth, namely the pine boxes and coffins of the dead. Derry records extensive damage to skulls and bones generally by termites in graves in Egypt and Nubia,[3] and these insects have been observed in several localities swarming in cemeteries. Furthermore, they often burrow deep into the earth, especially where they can follow down decaying wood, as in the woodwork of wells, etc. G. A. Dean, entomologist of the Kansas State Agricultural College, Manhattan, Kans., states that McCulloch observed a swarm of termites in a cemetery at Anthony, Kans., on January 19, 1914, in which the winged insects[4] came out in enormous numbers and the ground was actually covered with them in several parts of the cemetery. The temperature at this time was about 70° F.

DAMAGE TO STORED MATERIAL.

Wooden electrotype blocks (in New York, N. Y.) and other wood products, books in libraries or elsewhere, pamphlets, paper, documents (Pl. VI, fig. 1), and plans (Pl. VI, fig. 2), wood-pulp products,

[1] In California termite damage includes also that by *Termopsis angusticollis* Walker.

[2] In southern Georgia and the Gulf States termite damage to poles of bald cypress and southern white cedar (*Chamaecyparis thyoides*) includes also that by *Calotermes* sp.

[3] In many graves in Egypt and Nubia bones are found to be covered with a shell of earth; also in mummified bodies, where less bitumen or other preservative substances were employed, termites were able to make way through the cloth in which the body was wound, damage always being associated with earthwork and tunnels.

[4] Probably *Leucotermes lucifugus*.

PRESSED WOOD-PULP TILE MINED BY TERMITES. BILOXI, MISS. (ORIGINAL.)

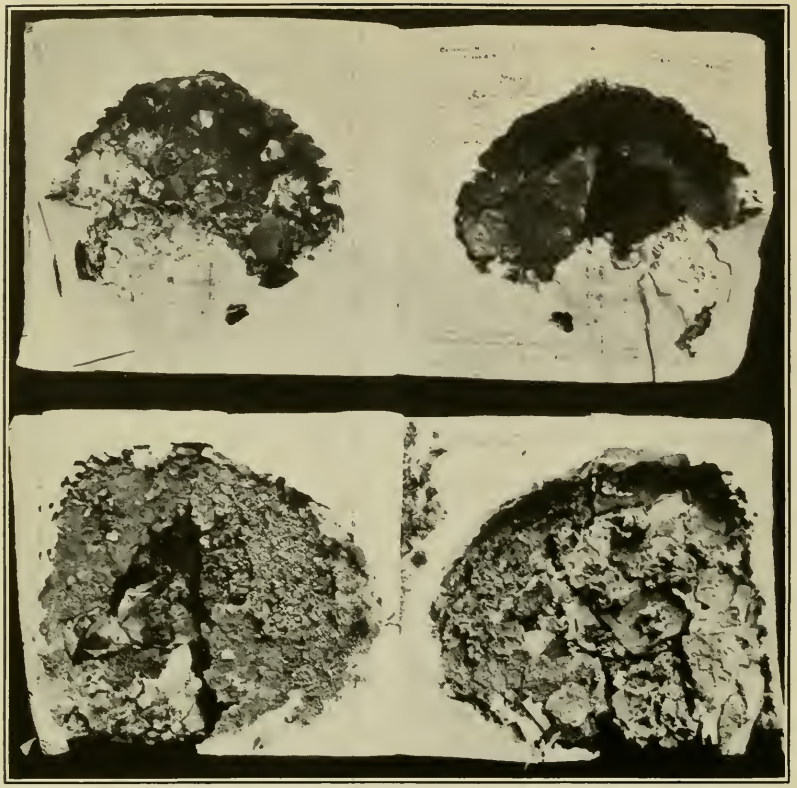
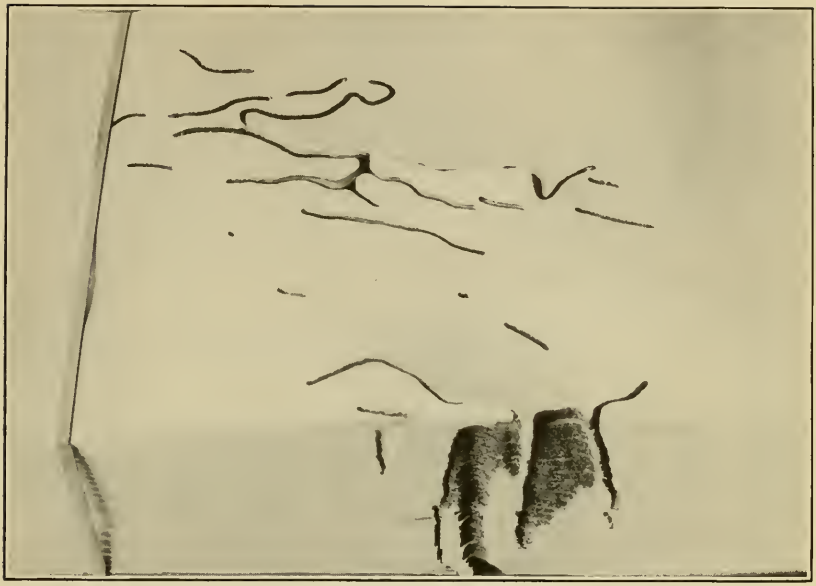
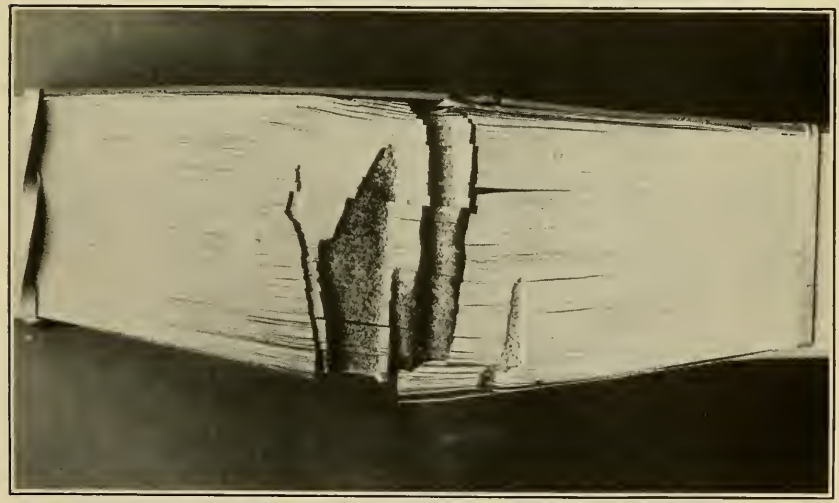


FIG. 1.—Termite work on railroad documents, Victoria, Tex., November 10, 1904. Photograph by W. E. Hinds. (Original.)

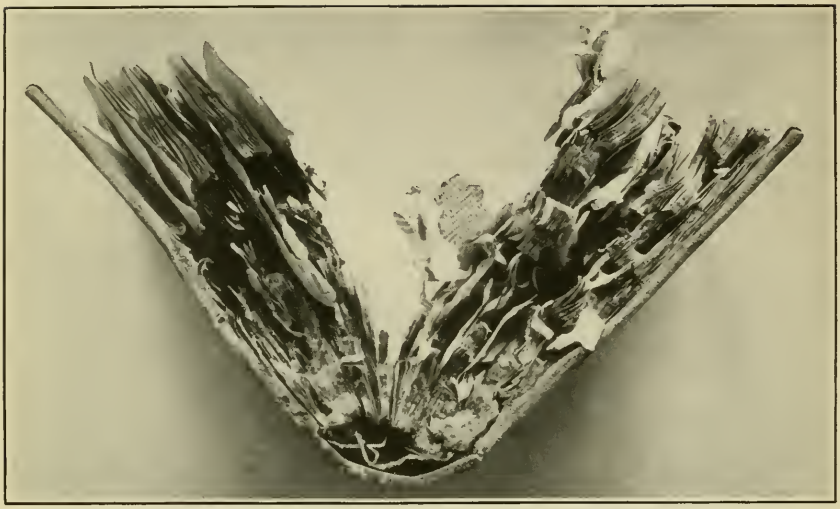
FIG. 2.—Plans at Washington (D. C.) Navy Yard damaged by *Leucotermes flavipes*. January, 1913. Photograph by C. H. Popenoe. (Original.)

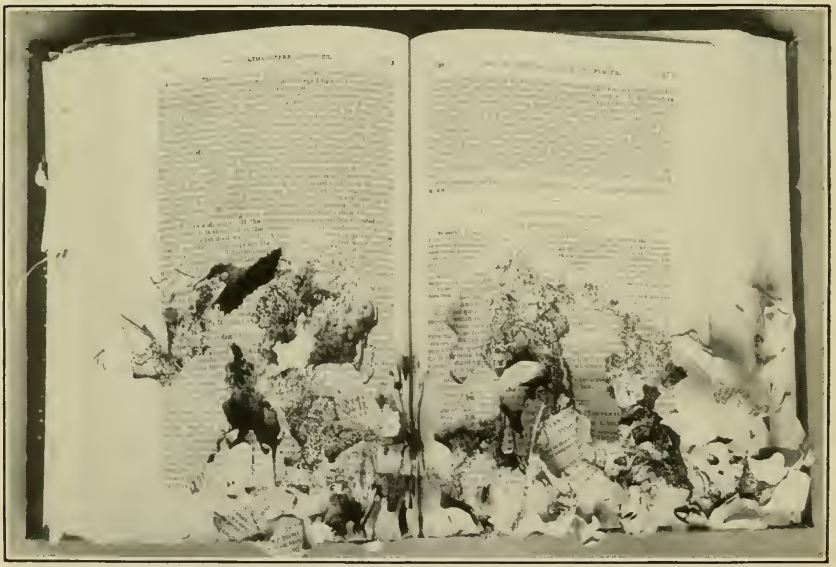




Stored paper burrowed by termites (*Leucotermes flavipes*), the edges of the mines being covered with excrement. Atlanta, Ga. (Original.)

DAMAGE BY TERMITES TO STORED PAPER.





Book from library at Van Buren, Ark., ruined by termites. June, 1915. Views of book open and on end. (Original.)

VIEWS OF BOOK IN LIBRARY DAMAGED BY TERMITES.

pasteboard, rolls of cloth, and other fabrics, clothing, shoes, and other leather products, as well as food stored in dark, damp basements or similar moist places where the ventilation is poor, are sometimes seriously injured or destroyed by termites. At St. Louis, Mo., December 21, 1889, according to a correspondent of the Bureau of Entomology, termites bored through a full bolt of "Conestoga" ticking into wood about one-fourth to three-eighths inch in thickness. The ticking had been lying on a shelf for about a month and was covered with excrement where bored. Cotton yarn stored in a mill (Raleigh, N. C.) and cotton goods (Vincennes, Ind.) have been reported to be injured by termites. Entire stacks of books and paper (Pls. VII and VIII) are often completely penetrated and ruined by the burrows of these insects. W. S. Abbott has referred me to an instance at Manchester, N. H., where, according to E. J. Burnham,[1] documents were damaged in a cement vault in a basement, the insects probably entering in with the pine boards sheathing the vault. Similar cases have been recorded in Washington, D. C., and elsewhere. Termites usually infest this class of material indirectly through the moist or decayed wooden flooring, shelving, or casing on which the products are stored. At Cazenovia, Ill., paper lining under rugs and the carpets and rugs, where in their path, were eaten through, the insects coming up through the infested flooring underneath.

Some unusual cases of injury to other stored products have been furnished by F. H. Chittenden, in charge of Truck Crop and Stored Product Insect Investigations in the Bureau of Entomology; i. e., samples of flour received from New Orleans, La., in which were large lumps containing burrows made by *Leucotermes flavipes*, a few dead insects being still present in the same. The sacks containing this flour were unloaded on a platform under cover about the middle of November. The bottom sacks were cut as with a knife immediately above the floor and in these bottom sacks the lumps of flour were found that contained the white ants. Some sacks and bags received containing rice were injured in about the same way. The bottoms were eaten out of the sacks and the insects, by means of an adhesive substance, caused the rice to stick together at the bottom of the sacks. Another case of injury to stored rice occurred at Baton Rouge, La. Peanuts in store have also been attacked. On May 9, 1910, many layers of damaged bandage muslin (Pl. XIV, fig. 2), which had been lying on a wooden floor, were received from a Philadelphia hospital. The correspondent stated that this had happened a number of times.

[1] Burnham, E. J. Damage by white ants. *In* Nature Study, v. 3, no. 2, p. 201–203, Manchester, N. H., April, 1903.

DAMAGE TO FRUIT, NUT, SHADE, AND FOREST TREES.

Termites occasionally injure a great variety of living trees, bushes, and shrubs. In Florida, according to H. G. Hubbard, termites have caused considerable damage to newly planted groves of orange trees, the bark being eaten away about the collar and root and the tree completely girdled. There have been many records since then of injury to young orange trees in newly cleared land (Marlatt). Similar damage by termites[1] has been recorded to apple, pear, cherry, and plum trees in the Southern States and California,[2] the roots being attacked or the trees injured near the base. H. S. Smith states[3] that "termites were reported to be damaging lemon trees in the vicinity of Germantown" (California). On May 17, 1890, a piece of solid pear root damaged by termites was sent to the Bureau of Entomology from Mineral Park, Mohave County, Ariz. On May 9, 1902, a similarly damaged root of apple stock was submitted to the bureau from Moran, Okla.

Such damage is more common in the new soil of recently cleared woodland containing old decaying stumps or much humus. Similar damage by *Leucotermes* spp. is recorded to pecan, chestnut, and walnut.

Comstock records damage of the same kind to guava bushes in Florida, at or just below the ground.

In cities shade trees in great variety are injured by termites, the insects infesting the roots and the heartwood at the base of injured trees. Sometimes the infested trees are plastered with earthlike tubes or galleries.

In the forest termites rapidly[4] render insect, fire, and disease killed timber unmerchantable. They also damage the roots and lower trunk of injured living trees, especially oak and chestnut, sometimes following the attack of large wood-boring beetle larvæ.[5] In a letter dated October 24, 1915, A. B. Champlain states: "Termites are very bad on hickory saplings at Lyme, Conn. They quickly attack the infested trees, utilizing the Magdalis galleries, Goes galleries, or any other mode of entrance; in wounds on green trees as well as in trees of every stage of decay." Where the heartwood is decayed in living trees or in dead standing trees termites will work for considerable distances above ground (40 to 50 feet), completely honeycombing the interior. (Pl. IX, fig. 1.) The earthlike tubes, in the form of

[1] *Leucotermes* sp.

[2] Essig, E. O. Injurious and Beneficial Insects of California. Supplement Mo. Bul. State Com. Hort. California, v. 4, no. 4, 541 p. (p. 28–29), 503 figs., 1915. Damage by *Leucotermes lucifugus* to various species of fruit trees; i. e., apricot, cherry, lemon, orange, peach, and pear.

[3] Smith, H. S. *In* Mo. Bul. State Hort. California, v. 4, no. 1, p. 53, Jan., 1915.

[4] The rapidity of destruction varies with the resistance of the wood of the species of tree and the geographical locality.

[5] Prionidæ.

longitudinal tunnels or viaducts, constructed by termites often can be observed between crevices in the bark of infested dead and living trees to a considerable distance above the ground.

DAMAGE TO FIELD CROPS.

In the Southern States termites occasionally injure the stems and roots of a great variety of apparently healthy field crops, including both grain and truck crops, among which may be listed corn, cotton, sugar cane, rice, grasses, and a great variety of garden vegetables. In Kansas the species *lucifugus* is reported to inhabit dry vegetable and fibrous substances.

Injury of this character has been only occasionally recorded, and in consequence there has been, and is, considerable doubt as to whether termites are capable of attacking perfectly healthy living plants, it being usually considered that the plants attacked were previously either diseased or injured. However, termites are capable of such primary attack, although such injury in every case is not necessarily primary.

Comstock, as early as 1879, stated that in the Southern States termites infest living plants such as sugar cane (Florida) and pampas grass (Texas), attacking that part of the plant which is at or just below the surface of the ground. The bases or stalks of pampas grass are hollowed; in case of sugar cane the most serious injury is the destruction of the seed cane. On July 6, 1915, T. E. Holloway found workers and soldiers of *Leucotermes* sp. in burrows of Diatraea in sugar cane at New Orleans, La.

Kent states that at Roxie, Miss., termites[1] destroyed a good many cotton stalks during the summer of 1887, attacking the stalk just below the soil and eating out the interior, which would kill the plant in every instance.

F. H. Chittenden records injury to roots of cranberry at Bordentown, N. J.; also, in cases where the species of termite was not determined, to young squash plants at Brownsville, Mercedes, and Mission, Tex.

COTTON.

W. D. Hunter, in charge of Southern Field Crop Insect Investigations, has furnished the following field notes.

H. Pinkus, on June 22, 1910, in a cotton field on an irrigated farm at Lampasas, Tex., noticed many dead plants and some dying at certain places between healthy plants. Upon digging up the ground he discovered termites[2] destroying the stem about 2 inches below the surface of the soil, a hole being bored through the stem and into the heart of the plant; some plants were recently killed. Pinkus stated that on June 30, 1910, in a cotton field at Granbury,

[1] *Leucotermes flavipes.* [2] *Leucotermes lucifugus.*

Tex., a number of dead plants were found that had been killed by termites. (Pl. X, fig. 1.) On July 2, 1910, in a field at Pearsall, Tex., a large cotton plant that had borne fruit was found already wilted, evidently very recently. When the soil was dug up about 3 inches deep from the surface and the plant moved, the stalk came off, clean cut, and the termites came out of its heart; the lower part of the plant was gone and only a few small roots could be found. E. S. Tucker states that on July 12, 1910, an examination of a cotton field at Plano, Tex., showed termites present and working in a few roots that had been killed by a root-rot disease; the stalks had been dead and dry for some time. The roots were badly bored. (Pl. X, fig. 2.)

POTATOES.

Injury by termites to potatoes has been recorded by C. L. Marlatt,[1] who states that a very common form of injury to those growing in rich soil or where there is a considerable quantity of decaying vegetable matter has often been noted. F. A. Marlatt discovered that white ants caused the damage, the injury to the tubers having the form of scars or pits covering the surface, the pits varying in shape from irregular holes to long, irregular excavations, sometimes extending far into the potato, but commonly to a depth of from one-eighth to one-fourth of an inch. In all cases these pits are more or less overhung and covered by the dead and dying skin, and are also lined with the cellular tissue of potato, showing that the insect cares most for the starch and water of the tuber. C. L. Marlatt now believes that the termite injury to the potato may possibly be secondary to that caused by the scab disease, since white ants frequently eat out scabby spots on potatoes. In the Tropics, however, otherwise sound potatoes are attacked by termites.

H. M. Russell found that sweet-potato tubers at Cutler, Fla., were being injured, the termites mining through the tuber and eating out nearly the entire interior. In most cases the insects entered the roots of the plants just below the earth and tunneled the stems. It is possible that termites similarly injure other tubers, as radishes, although there are no definite records. At Sabinal, Tex., on May 29, 1910, F. C. Pratt exposed a small colony of termites[2] in the ground while digging radishes.

CORN.

Injury by termites to corn has occasionally been recorded, as may be noted from the following field records of F. M. Webster, late in charge of Cereal and Forage Insect Investigations. G. G. Ainslie states that at Clemson College, S. C., on August 5, 1908, several dead stalks of corn were found in a cornfield: they proved to be hollowed out inside and

[1] Marlatt, C. L. The White Ant. U. S. Dept. Agr. Bur. Ent. Circ. 2d ser. no. 50, rev. ed., 8 p., 4 fig., January, 1908.

[2] *Eutermes* sp.; colonies commonly are found in the earth in the Southwest.

FIG. 1.—Heartwood of living chestnut tree disintegrated by *Leucotermes* sp. Falls Church, Va. (Original.)

FIG. 2.—Small corn plants with the "bud" killed by termites. These insects cut a hole into the stem at the base, severing the central shoot, which is dead at the top. Hurricane Mills, Tenn., June 19, 1912. Photograph by G. G. Ainslie. (Original.)

FIG. 1.—Cotton roots injured by termites. Granbury, Tex., June 30, 1910. Photograph by H. Pinkus. (Original.)

FIG. 2.—Cotton roots affected by root-rot and attacked by termites. Plano, Tex., July 12, 1910. Photograph by E. S. Tucker. (Original.)

DAMAGE TO COTTON PLANTS BY TERMITES.

full of white ants.[1] In every case, however, the stalk showed that it had been attacked first by the larger corn stalk-borer (*Diatræa saccharalis* Fab.) and drilled about the base. It could not be determined whether the plant was dead when the white ants attacked it or whether they killed it. The stalk was drilled out and hollowed up to about 10 inches from the ground. The plants when killed were about 2 feet high. On October 30 Ainslie again found many stalks of corn full of white ants. The stalks which contain the termites can be ascertained as soon as touched. In most cases the entire inside has been eaten out, leaving a thin shell with a plug of untouched pith at the top. The stalk was usually entered at the bottom, underground. No forms but workers could be found. About 5 per cent of the stalks were infested, and each one contained from 5 to 75 workers.

Ainslie states that at Hurricane Mills, Tenn., June 19, 1912, in a field of young corn, numerous plants were found with these insects[1] mining in the ground and even up into the stalks. In most cases there was evidence to show that the termites had been attracted by some previous work of another insect and had merely kept on and enlarged the holes already started. These plants, by their dwarfed and deformed appearance, usually indicated the nature of the previous work. However, some plants were found which had been injured solely by these white ants. The plants were healthy and normal except for a wilting of the central leaf or two. The termites had cut smoothly elliptical holes into the stalk just below the surface of the ground, but these holes were too far above the roots to be those of any kind of "budworm." Within the holes the termites had excavated upward, taking the central core cleanly out, so that the amputated leaves would almost fall out in the wind. The colonies were not large, and it may be that the insects worked through passages from one central nest. This ground had been cleared many years and there were then no stumps or other rubbish in the field. (Pl. IX, fig. 2, shows the manner of injury.)

Similar injury to the stalk and taproot of corn has been recorded by several others in the field in North Carolina, Tennessee, and Alabama, the injury sometimes being primary, all castes being found in the stalks, and the insects apparently making permanent habitations in the plants. Termites breed in the stubble in the autumn, winter, and early spring, and later sometimes attack the young plants or the seed.

In Kansas E. O. G. Kelly made observations indicating similar injury to corn in the field. At Wellington, Kans., on August 8, 1910, he states that several colonies of termites[2] were burrowing in cornstalks. Some of the stalks had been bored for three to four joints,

[1] *Leucotermes flavipes.* [2] *Leucotermes* sp. (probably *lucifugus*).

and the joints were simply shells. The tops of the plants attacked were dying. The termites seemed to prefer the pith. Some of the colonies were quite large and had attacked two or three stalks in one hill. On the 12th of August termites were active in five different cornfields. They had not attacked many plants in any area, but had severely bored those that were attacked, great hollows having been made by them. Some of the injured stalks had been previously attacked by *Sphenophorus maidis* Chittn., or other insects, but not all of them. The insects seemed to enter at a scar or break about the roots; none were above the ground. On the 22d of August Kelly found that quite a number of corn plants had been attacked by these insects and that the stalks were mere shells, having had the pith removed. No serious injury appeared to have been done to the plants, because most of them were small. By September 6 the corn plants were getting quite dry and the termites seemed to be increasing. In a cornfield on one farm there were numbers of attacked plants. This field was an old prairie field and had been planted to corn the year before. There were no decaying stumps or wood of any kind in the field, and the termites evidently subsisted on the cultivated crop. On October 14, 1910, the termites were still active, burrowing in the dry cornstalks. A colony dug out contained thousands. The ground was filled with their burrows. Their nest did not seem to be anything but a series of burrows with young larvæ, etc., here and there all through them. On November 26 the termites were still burrowing in the stalks. On February 15, 1911, with the temperature at 75° F. and the ground quite warm at noon, there was a swarm in a cornfield, along roadsides, and even from sidewalks in the city limits. On May 9 many termites were found in a cornfield that was planted to corn the year before; nine young plants had been injured. Single dead stalks sometimes contained 32 termites.

Similar damage to a living corn plant about 1 foot high, tunneled by white ants and not previously injured, was found by J. J. Davis on June 18, 1915, at West La Fayette, Ind.

H. E. Smith states that on May 8, 1913, in a field of corn 1½ miles northwest of Mulvane, Kans., he found that this species[1] had eaten all the seed before germination in about 6 feet in the row, and they were apparently working straight down the row. No others could be found in the field.

DAMAGE TO NURSERY STOCK, YOUNG PLANTATION STOCK, AND VINEYARDS.

There are numerous records of termite injury to young fruit and nut-tree seedlings in nurseries, to other nursery stock, and to young trees planted in recently cleared ground or soil rich in humus. The

[1] *Leucotermes* sp. (probably *lucifugus*).

injury, however, has been only occasional and not extensive, and usually has not been considered serious. The stock is usually attacked at a scar, where the roots have been injured or cut off, or at a graft, as "cleft-graft" apple stock.

APPLE.

At Wellington, Kans., on November 14, 1910, E. O. G. Kelly states that on several occasions dying and dead apple sprouts in a nursery had been severely burrowed. An examination of 3-year-old stock showed that the roots and body of a number of the trees had been burrowed in the same manner as the sprouts, and the termites[1] were in the burrows in these larger trees. About 5 per cent of the stand would have to be discarded on account of their ravages. The pest had been injurious for a number of years and was worse in dry years than in wet. The 3-year-old trees were quite badly damaged when they were put out in 1909, because the early spring was so dry. The 2-year-old trees were not very badly infested during the fall of 1910. Quite a number of young sprouts were girdled, and the result of girdling is a dead tree. A count in three rows of the 2-year-old stock gave results of 8, 7, and 12 per cent, or an average of 9 sprouts out of every 100, infested. In the spring or 1-year-old stock the infestation was quite severe. The rows near the hedge fence were 15 to 30 per cent infested; out farther, from 6 to 70 per cent were infested. The severe infestation ran in local spots, not being general over the field, but there were infested plants in all parts of the field (Pl. XI). An adjoining cornfield was badly infested, numbers of stalks being bored by them. Some of the trees were full of the insects, while some had been abandoned. On November 26 the termites were still active and burrowing in the apple sprouts. Peach sprouts and shade-tree sprouts in the same nursery were injured.

PECAN.

Herrick states that in Mississippi, in a pecan nursery where there was damage by termites, injury was most prevalent to seedling pecans of the 1-year growth.

A. L. Quaintance, in charge of Deciduous Fruit Insect Investigations, states that numerous reports relative to injury to pecan nursery trees by white ants have come from various parts of the pecan-growing area, as Texas, Florida, Mississippi (Pl. XII), Louisiana, etc. W. B. Wood investigated a case of serious infestation of a pecan nursery in the neighborhood of Petersburg, Va. An inspection, on October 8, 1912, of this nursery, which consisted largely of pecan trees varying in age from 1 to 4 years, showed that the severest injury to the

[1] *Leucotermes* sp. (probably *lucifugus*).

trees occurred on stock 1 and 2 years old. Trees that had reached an age of 3 years showed little injury. This difference was probably due to the fact that the trees 1 and 2 years old were planted on recently cleared woodland, whereas the old trees were on old land, though closely adjacent to the badly infested area. Of the trees 1 and 2 years old probably one-fourth of the total number had been destroyed during the summer, the injury being almost entirely below ground, although the excavations made by the termites occasionally extended an inch or two above the surface of the soil inside of the tree. Below ground the trees were frequently hollowed out until little more than a shell of bark remained. The insects made their entrance to the trees at some point below ground, the place most frequently chosen being the point where the taproot had been cut to cause it to branch out into a larger root system. From this point of entrance the insects worked upward, extending their galleries through the wood and enlarging them until the heart of the tree at the crown was entirely eaten away. Usually the affected trees did not show any indication of injury until they were badly damaged and then they died very quickly, the leaves sometimes drying on the limbs within a period of three or four days.

VINEYARDS.

Injury by termites to vineyards has occasionally been recorded in Algeria,[1] in Bordeaux, France, and in North America. Usually only the weak or old vines with many pruning scars are attacked, or dead or injured parts, or ramifications of the stem or branches invaded by other pests, the healthy ramifications of the stock being exempt from invasion. Signs of attack are sickly foliage or abortive buds, or the injury is observed at the time of cutting down to stock or making graftings. S. H. Scudder records fatal injury to the roots of grapevines in forcing houses at Salem, Mass.

DAMAGE TO SHRUBS, FLOWERS, AND GREENHOUSE STOCK.

GREENHOUSE STOCK.

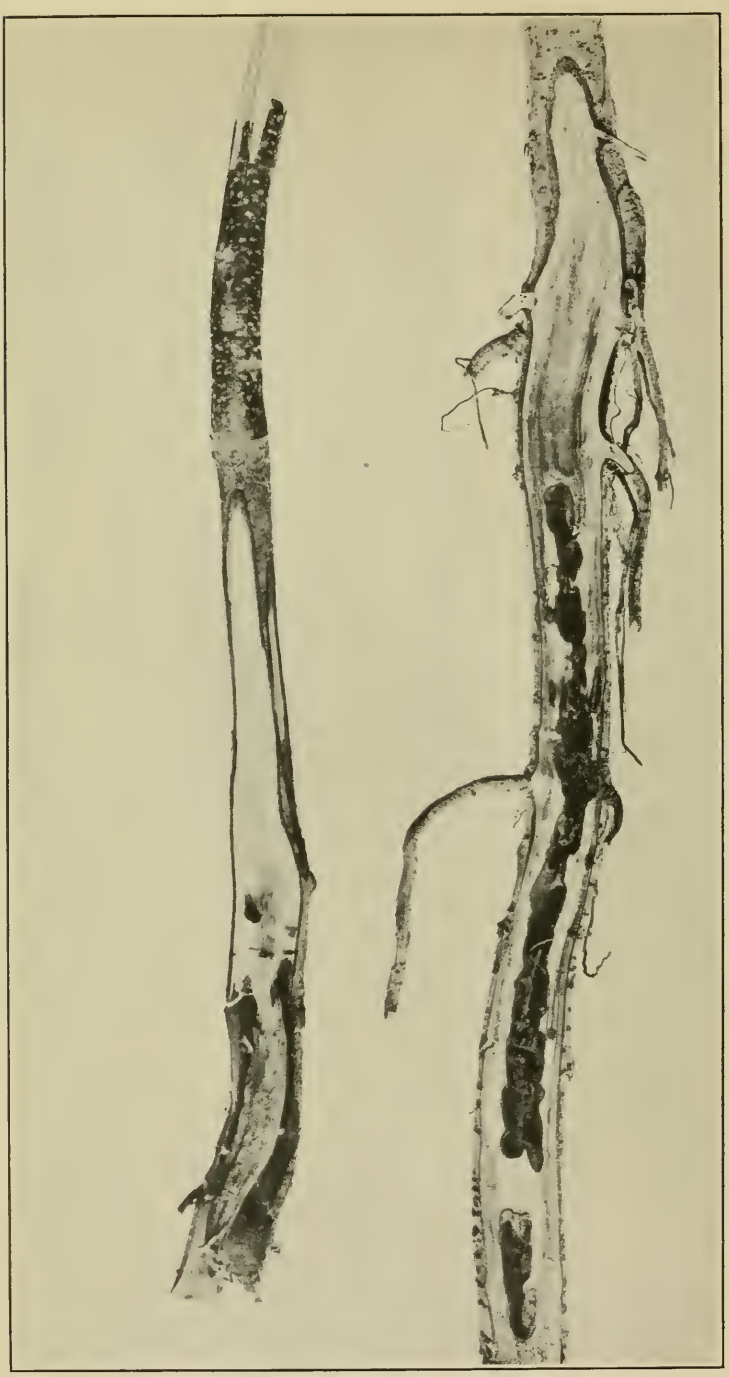
Termites injure a variety of shrubs, flowers in gardens as well as in greenhouses, and weeds. Hagen states that our common native termite,[2] introduced into Europe, so nearly destroyed one of the largest of the beautiful hothouses at Schoenbrun belonging to the Emperor of Austria that it had to be torn down. Besides the beams, the termites destroyed the tubs in which the plants were set. Hagen states in 1876 that a few years before he had observed termites swarming in clouds in the Botanical Garden at Cambridge, Mass. Manured

[1] By *Calotermes flavicollis* Fab.

[2] *Leucotermes flavipes.*

TERMITE DAMAGE TO NURSERY STOCK.

Damage to apple seedlings by *Leucotermes* sp. at Wellington, Kans. November, 1910. Photograph by E. O. G. Kelly. (Original.)



TERMITE DAMAGE TO NURSERY STOCK.

Pecan nursery stock killed by *Leucotermes flavipes*. Wortham, Miss., July 14, 1913. Photograph by J. H. Paine. (Original.)

TERMITE DAMAGE TO GARDEN PLANTS.

Geranium stems burrowed by "white ants." Damage extensive in lath house and garden at Brownsville, Tex., 1915. Photograph by C. H. Popenoe. (Original.)

flower beds around the walls of wooden buildings are a source of infestation by termites. The soil in such beds is always less compact and warmer, and termites have been observed by Hagen swarming from such beds.

Webster states[1] that in 1896 termites were destructive in Ohio, burrowing in the roots of small trees. He figures the injuries to geranium cuttings that were being propagated in a greenhouse near Cincinnati, the termites destroying many cuttings by eating them off the benches.

Chittenden states that the common white ant (*flavipes*) was recorded some years ago as occurring quite commonly on plants grown under glass, and that it is directly injurious to such growing vegetation as greenhouse geranium (Pl. XIII), chrysanthemum cuttings, and other herbaceous plants, especially those with large stems or more or less woody stalks. The stalks found to be injured had been tunneled through and through by the white ants, and at the bottom near the roots the plants had given way to the inroads of numerous individuals. Several plants were killed outright. The causes of such attack can easily be traced to the colonies in old sticks that are used for recording the date of setting out, etc., and the termites mining in wooden benches. One such case was reported by L. C. Corbett, of the Bureau of Plant Industry, who stated that large begonia plants at Morgantown, W. Va., had been injured in a similar manner. Infestation was due to the undermining of the bench structure beneath the plants, the insects having burrowed through the wood up through the drainage holes in the bottoms of the pots. Florists are sometimes sorely tried by these insects and state that "they attack everything." Roses grown in greenhouses are sometimes badly injured by the girdling of the white ants. While partial to geraniums and chrysanthemums, termites, as shown by the records of the Bureau of Entomology, injure jasmine, pansies, and oleander. Wooden benches and plant pots are infested, as well as the woodwork of the buildings, the insects coming up through the ground from outside colonies. Termites may be considered a serious greenhouse pest. According to G. A. Dean, entomologist of the Kansas State Agricultural College, on January 29, 1915, termites[2] swarmed in a greenhouse; there was a swarm in the same greenhouse on December 26, 1914. W. E. Britton states[3] that more than 200 geranium plants had been ruined by termites,[4] which tunneled out the inside of the stem and main roots in the field at New Rochelle, N. Y.

[1] Webster, F. M. Some Particularly Destructive Insects of Ohio. Ohio Agr. Expt. Sta. Bul. 68, p. 19–58, 6 pls., 1896.

[2] *Leucotermes lucifugus.*

[3] Britton, W. E. Injury to Geraniums by White Ants. *In* 14th Rpt. Connecticut State Ent. f. 1914 (Conn. Agr. Expt. Sta. Rpt. f. 1914, pt. 3), p. 196–197, 1915.

[4] *Leucotermes* sp.

ORNAMENTAL PLANTS.

F. C. Pratt states that at Sabinal, Tex., on July 11, 1910, some small pieces of Opuntia infested with Mimorista larvæ were entirely covered with soil galleries by termites. Many insects were found. It was also noticed that the galleries were extended to the healthy plants. Most of the small pieces were shriveled, but this condition was primarily due to the termite attack. This injury to ornamental cacti has occurred many times before.

On August 24, 1915, at Jacumba, Cal., F. P. Keen found workers and soldiers of *Hamitermes* sp. feeding on the surface of the rind of Yucca, where protected by the leaf bases, which are closely appressed to the stalk. The insects worked between the rosette of leaves and the flower stem. Jacumba is near the International Boundary Line and in a desert region.

At Washington, D. C., termites (*L. flavipes*) constructed earthlike tunnels around a wooden fern box in a window of a school building in October, 1915. When the insects came to a hole in one corner of the box—bored to allow the excess water to drip away—they suspended hanging tubes down through this hole. These were about 3 inches in length and 1½ inches in width at the bottom—the widest point. The opening at the bottom, through which the antennæ of the workers and soldiers could be seen projecting, was about ¼ inch in diameter. The shape of these tubes was somewhat like a funnel but the flare was not quite so marked. Termites infest the roots and stems of ornamental plants, in gardens or potted.

WEEDS.

E. S. Tucker states that on July 30, 1909, at Dallas, Tex., termites[1] occupied the hollow roots of a weed, *Leptilon canadense*. The insects had effected entrance through a hole in the root. On September 29, 1911, at Wellington, Kans., according to E. O. G. Kelly, termites had attacked stems of cocklebur, utilizing the entrance hole made by *Papaipema nitela* Hbn. At Colorado Springs, Colo., on March 7, 1915, at an elevation of 6,100 feet, live termites[1] were noted by G. Hofer in the dead stem of the common thistle.

PREVENTIVE AND REMEDIAL MEASURES.

PREVENTIVES.

PROTECTION OF WOODWORK IN BUILDINGS.

The fact that the beams, as "joists," "studding," "stringers," etc., of the basement are embedded in concrete is only a partial protection. In the settling of the house concrete is almost sure

[1] *Leucotermes* sp.

to crack, allowing avenues of ingress, and the beams and joists put down in the moist material soon partially decay and become exceptionally good breeding places. From such beams the white ants carry their burrows up through the timbers of the first and even second floors (Marlatt). Flooring commonly becomes infested through the wooden beams or stringers laid directly on the earth or in moist concrete; untreated beams should never be laid on the earth and the spaces filled in with concrete, or in moist concrete, since they will rot, even if they do not become infested. An air space should intervene. Therefore the foundations of buildings should be entirely of brick, stone, or concrete, including the basement floor, without beams or joists sunken in the ground or concrete, and especially should this method of construction be followed in tropical and subtropical regions. H. von Schrenk, of St. Louis, Mo., states that in no case should timber joists be completely surrounded with mortar or brick; there should be an air space completely around the joists so as to permit air circulation.

Marlatt states that complete dryness is an important means of rendering buildings safe from attack. Books and valuable documents, etc., should not be packed away in unventilated chambers where they may become moist and moldy, as they are then particularly subject to attack by white ants, which are very likely to be present in old buildings, even though their work has not been sufficient to bring them into special notice.

USE OF RESISTANT WOODS.

Certain species of woods are highly resistant to termite attack, due to the presence of oils, alkaloids, gums, or resins as well as to hardness and other factors.

Maj. George Ahern, United States Army, reports, according to Marlatt, that California redwood has been used for more than 25 years in the Philippines and has never been known to be injured by white ants. Its use in Manila is very general, especially in the construction of cabinets, filing cases, etc., where it is desirable to protect valuable papers from these insects. Redwood is not resistant against termite attack in contact with the ground in California.

Another resistant North American cabinet wood is black walnut; of the tropical species, teak, mahogany, and "peroba" are resistant woods.

As to timber to be set in contact with the ground, E. Gerry gives data[1] on the durability of native hardwoods; of the conifers, incense cedar, eastern red cedar or juniper, western red cedar, and southern bald cypress are resistant. Durable and resistant exotic structural

[1] Gerry, Eloise. Tyloses: Their occurrence and practical significance in some American woods. *In* Jour. Agr. Res., v. 1, no. 6, p. 445–470 (p. 463–464), pl. 52–59, Mar. 25, 1914.

timbers are teak, greenheart, lignum-vitæ, etc. "Karri" (*Eucalyptus diversicolor*) and "jarrah" (*E. marginata*), of Australia, are resistant although not immune to attack by termites.

REMEDIES.

LOCATION OF DAMAGE TO WOODWORK IN BUILDINGS.

The point of emergence of the flying termites may indicate approximately the location of the infested timbers; if the insects are not observed swarming, large numbers of the dead winged adults or the discarded wings will be found near by. Frass and earth thrown out of crevices through which the insects emerge are also evidence. In efforts to stop further damage by termites in buildings it should be realized that the numbers of these insects may be constantly recruited from some undiscovered, outside central colony. The destruction of the winged, colonizing adults at the time of the emergence, while advisable in preventing the establishment of potential new colonies, is of no value in eradicating the insects infesting the woodwork.

Another indication of infestation is the presence of longitudinal earthlike tubes, of small diameter, constructed on foundation timbers or other woodwork, or over the surface of stone, brick, or other impenetrable foundation material from the ground to the woodwork. Drenching the ground—where these tubes originate—with kerosene oil will afford relief. A prompt examination of the foundation timbers, such as beams and joists in contact with the ground, should be made to determine the approximate point of entrance of the insects and the extent of the damage already accomplished. It may be necessary to tear up the flooring and other woodwork to accomplish this. The foundation timbers and interior woodwork found damaged should be removed and burned and the ground where they were set drenched with kerosene oil.

ROCK FOUNDATIONS AND WOOD PRESERVATIVES.

The main point is to prevent the insects from gaining access to the woodwork from colonies in the ground, either by means of substituting rock or concrete foundations and concrete or tile flooring in the basement or by protecting the foundation timbers in contact with the ground by impregnation of the wood with coal-tar creosote.

It is very rarely possible to find and destroy the external colony, and it may be necessary to replace the foundation of the buildings with walls and floorings of stone, concrete, or other form of rock composition, and this is the most permanent and complete preventive. In the case of the National Museum buildings, the Carnegie Institution of Washington, and several private edifices in Washington,

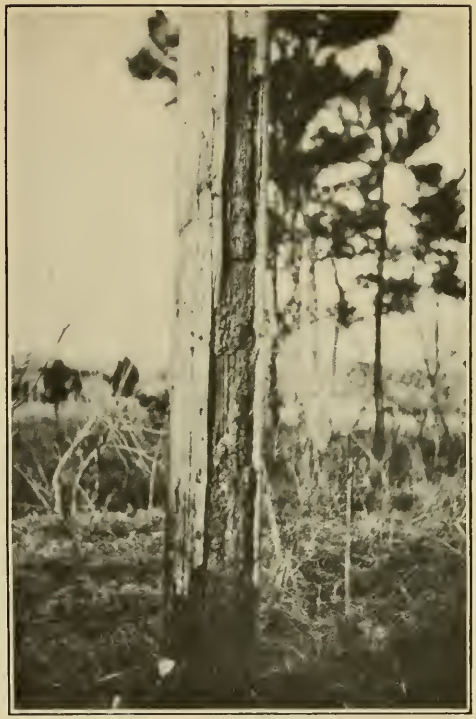


FIG. 1.—Injury by "white ants" to yellow-pine pole impregnated with 12 pounds of coal-tar creosote per cubic foot in a telephone line set along Gulf coast near Pass Christian, Miss., since 1899. Average penetration of the preservative, 1¼ inches; surface intact; insects entered through deep season checks; damage more extensive above ground line. Shell of outer layers of wood broken away to show eaten-out interior. Photograph by American Telephone and Telegraph Co. (Original.)

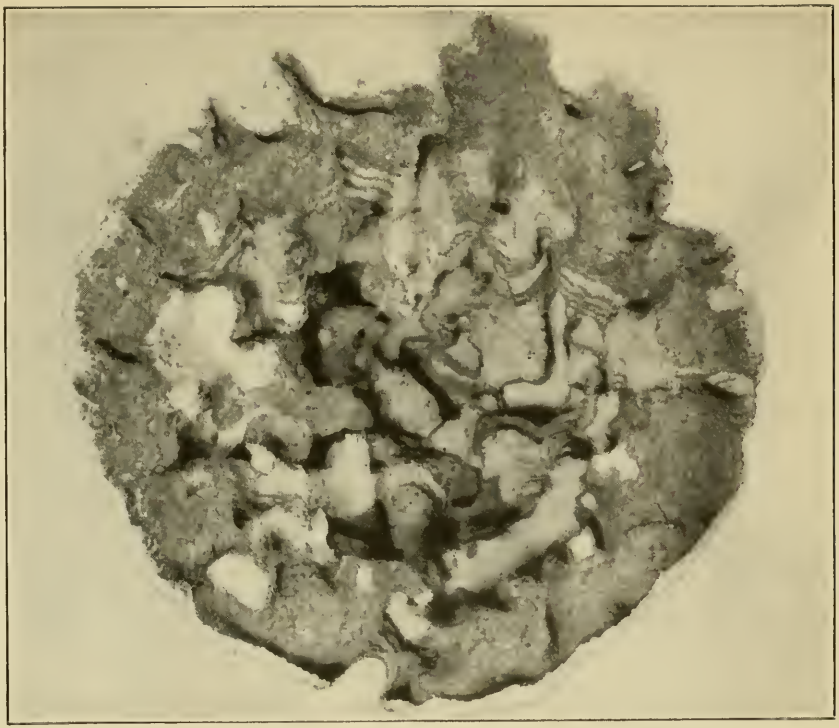


FIG. 2.—Layers of bandage muslin lying on wooden floor of a hospital in Philadelphia, Pa., destroyed by termites. Photograph by C. H. Popenoe. (Original.)

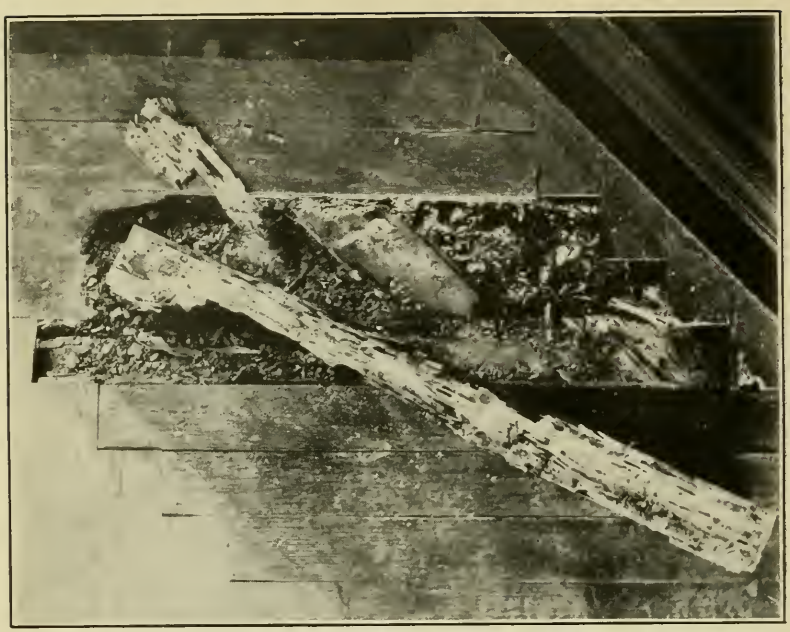


FIG. 1.—Oak floor honeycombed by *Leucotermes flavipes*. Washington, D. C., July, 1915. Photograph by C. H. Popenoe. (Original.)

FIG. 2.—Pine subfloor underneath the oak floor shown in figure 1. Photograph by C. H. Popenoe. (Original.)

D. C., this course was finally adopted, with the result that white ants were completely excluded and their work terminated (Marlatt). This measure was also necessary in the case of the buildings of the State Agricultural College at Manhattan, Kans., where wooden partitions, floors, and other woodwork were torn out and cement floors and walls substituted.

If the foundation of the building is such that damage to the woodwork is extensive and likely to recur, and it is impracticable to replace with concrete or stone, it is advisable to replace the exposed interior woodwork with wood impregnated by a 6 per cent solution of zinc chlorid or a 1 per cent solution of bichlorid of mercury; except in case of flooring in contact with the ground or in wet situations, where such preservatives would leach out.

In case of greenhouses iron frames and concrete work should, wherever possible, replace woodwork, and woodwork should be impregnated with bichlorid of mercury. Wood impregnated with this preservative can be painted after treatment.

In some cases thorough and repeated drenching of infested timbers, where accessible, with kerosene oil may afford temporary relief and kill some of the white ants. Kerosene oil should be poured into the crevices through which the winged insects emerge from infested wood. As the insects may have entered the house through soil channels by means of pillars or the supports of porchings and steps, these last should be removed if damaged and the ground soaked with kerosene.

OTHER TIMBER IN CONTACT WITH THE GROUND.

Poles,[1] mine props,[2] railroad ties, posts, construction timber, and other wood in contact with the ground should, since these insects attack all classes of wood to which they can attain access from the ground, be treated with chemical preservatives to render them more resistant to termite attack. Superficial methods, temporarily prolonging the length of service of timber, include brush and dipping methods of treatment. From experiments it has been determined that for timber in contact with the ground brush and dipping treatments with coal-tar creosote will render southern yellow pine resistant for at least two to three years in the Southern States and effective for from three to four years and longer. Under the closed-cylinder pressure process ("full cell" treatment) of impregnation of southern yellow-pine timber with coal-tar creosote, at least 16 years' service is attained in

[1] Snyder, T. E. Insects Injurious to Forests and Forest Products. U. S. Dept. Agr. Bur. Ent. Bul. 94, pts. 1–2, 85 p., 16 pl., 14 fig., 1910–1915. Damage to Telephone and Telegraph Poles by Wood-boring Insects. U. S. Dept. Agr. Bur. Ent. Circ. 134, 6 p., 3 fig., Mar. 7, 1911.

[2] Snyder, T. E. Insect Damage to Mine Props and Methods of Preventing the Injury. U. S. Dept. Agr. Bur. Ent. Circ. 156, 4 p., July 13, 1912.

the Southern States[1] (Pl. XIV, fig. 1). After many years' service there may be a deterioration in the treated wood. Other chemical preservatives are in use, but coal-tar creosote is usually the most effective preventive since it is also a fungicide and will not leach out in wet situations. For permanent timbers to be used in coal mines a pressure process with zinc chlorid has been found more suitable, according to tests conducted by the Forest Service.

CABINET WOODS.

Impregnation of cabinet woods, furniture, etc., with chlorinated naphthalene[2] is effective in rendering wood more resistant to termite attack; treated, perishable, northern cabinet hardwoods comparing favorably with untreated teak and mahogany after two and one-half years' test.

WOOD-PULP PRODUCTS.

Treatments have been tested for wood-pulp products, such as the various wood-fiber, "processed," or "composition" boards used for interior finish and as substitutes for lath, etc., when they are to be used in the Tropics and portions of the southern United States to prevent attack by white ants. It has been found that the practical method is to add various poisons during the manufacture of these boards.

Experiments with such poisons and insecticides as white arsenic, bichlorid of mercury, zinc chlorid, copper sulphate, sodium fluorid, phenol, and dihydrogen potassium arsenate (KH_2AsO_4) have been conducted by manufacturers upon the recommendation of the Bureau of Entomology. It has been determined that where insoluble chemicals were added in the process of manufacture of the board there was so low a retention that the cost rendered the treatment commercially impossible. Also in the manufacture of the board a large amount of water is employed which it is not practicable to save, and consequently a large amount of chemical, whether soluble or insoluble, is carried away. As yet the results of these tests do not warrant the drawing of definite conclusions.

Dihydrogen potassium arsenate is a powerful insecticide,[3] is soluble in cold water, and should prove as effective as the insoluble white arsenic. Sodium fluorid has been been proved, by experiments of A. L. Quaintance, an effective insecticide and is also being tested as

[1] In the Tropics and along the Gulf coast of the United States, where seasonal checking of timber is liable to occur after treatment and setting, a penetration sufficient to prevent white ants from infesting the timber through these checks should be secured. A more uniform penetration with a practical minimum to allow for checking, and a heavier impregnation (at least 15 pounds per cubic foot) are necessary. The depth of penetration can be determined roughly by the thickness of the sapwood.

[2] Process devised by the Western Electric Co., of New York.

[3] Information on this insecticide was obtained from the Branch of Southern Field Crop Insect Investigations from the experiments of B. R. Coad.

a treatment to render timber more resistant to attack by insects. Wood soaked in a 2 per cent solution is under test.

STORED MATERIAL.

Injury to books, paper, documents, and other stored material or products is usually indirect, the insects as a rule burrowing through such material only where it is in contact with infested wood. Hence, since the source of infestation is decaying wood, if the insects can be kept out of wooden structures this damage can be prevented. When once the source (white ants coming up through the earth where there is moisture) is shut off, the insects infesting stored material soon die out or can be killed by spreading out infested books, documents, and other stored material or products to dry in the sun or in an oven. Later they can be restored to the repaired building or a safer place. Most damage of this sort can be prevented by the substitution of concrete foundations to buildings or by using timber impregnated with coal-tar creosote.

FUMIGATION.

Where the injury is confined to books and papers, other stored material, or exposed woodwork and furniture, hydrocyanic-acid gas fumigation can be attempted, exposing if possible also, by opening up floors, the infested joists beneath and spreading out the books and opening cases and wardrobes. As hydrocyanic-acid gas is poisonous and dangerous, fumigation should be attempted only by those with experience.[1]

LIVING TREES.

Owing to the subterranean habit of termites, it is extremely difficult to prevent or remedy injury to living forest, fruit, or shade trees. Care should be taken that the trees do not become scarred near the base, in order to prevent heart rot and subsequent infestation. Proper clean forest, orchard, and horticultural management is to be recommended. Properly executed tree surgery[2] sometimes may be effective in repairing damage to valuable old trees. Dead and dying infested trees should be removed and burned. Prunings should not be left lying on the ground, but should be burned.

NURSERY STOCK, FIELD CROPS, AND VINEYARDS.

Injury to nursery stock will be most serious on recently cleared land where there is abundant decaying wood. Such débris, in which the insects breed, should be removed. In general, the use of recently

[1] For a description of the use of hydrocyanic-acid gas see Howard, L. O., and Popenoe, C. H., Hydrocyanic-acid Gas Against Household Insects, U. S. Dept. Agr., Farmers' Bul. 699.

[2] Collins, J. F. Practical Tree Surgery. *In* U. S. Dept. Agr. Yearbook for 1913, p. 163–190, pl. 16–22, 1913.

cleared land should be avoided in planting nursery stock. In case of nursery stock, Herrick recommends the growing of two or three cereal crops on newly cleared land before setting out pecan stock, and suggests experiments with commercial fertilizers. Experiments with commercial fertilizers and chemical compounds to determine whether they will serve as preventives are to be conducted by the Bureau of Entomology.

Sometimes injury by termites to corn in Kansas, according to Marlatt, is due to the method of plowing under old stubble, in which the insects breed. This practice should be discontinued if there is serious damage by white ants. Allowing the land to lie fallow for one year before planting should be of value; the same can be said of deep fall plowing. The practice of better farming methods, with rotation of crops, will prevent damage to field crops.

In case of vineyards care should be taken in pruning operations to reduce the surfaces cicatrized; all dead or diseased vines should be removed. Cuts should be painted over with coal tar. The various mastics employed in grafting may prove to be effective preventives. Prunings should not be left lying on the ground, but should be burned.

FLOWERS AND GREENHOUSE STOCK.

In case of flower or truck gardens, especially where near the woodwork of buildings, less animal manure should be used, in order to protect not only the building but also the plants.

In greenhouses the removal of decayed infested wood will prevent the plants from becoming infested in turn. Iron frames and concrete work should wherever possible replace woodwork, and woodwork should be impregnated with bichlorid of mercury. Wood impregnated with this preservative can be painted after treatment.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 344

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief.

Washington, D. C. PROFESSIONAL PAPER. January 18, 1916

STUDIES ON THE BIOLOGY OF THE ARIZONA WILD COTTON WEEVIL.[1]

By B. R. Coad,
Entomological Assistant, Southern Field Crop Insect Investigations.

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INTRODUCTION.

Early in 1913 it was announced by Mr. O. F. Cook of the Department of Agriculture that a weevil, apparently identical with the Mexican cotton boll weevil (*Anthonomus grandis* Boh.), had been found breeding in the fruit of a wild cotton plant (*Thurberia thespesioides*) in the mountains of southeastern Arizona.[2] This announcement was at once followed by explorations in Arizona to determine the distribution of the weevil and its host plant, and research work on the habits, life history, and economic importance of the species. Specimens were sent to the writer at Victoria, Tex., during the summer of 1913, and there as many as possible of their life functions were tested in comparison with the native weevils. Taxonomic study of the Texas and Arizona weevils showed the latter to be a distinct variety, and it was described by Mr. W. Dwight Pierce as *Anthonomus grandis thurberiæ*.[3] The biological investigations showed

[1] *Anthonomus grandis thurberiae* Pierce.

[2] Cook, O. F. A wild host plant of the boll weevil in Arizona. *In* Science, n. s., v. 27, no. 946, p. 259–261, Feb., 1913.

[3] Pierce, W. D. The occurrence of a cotton boll weevil in Arizona. *In* U. S. Dept. Agr., Jour. Agr. Research, v. 1, no. 2, p. 89–96, Nov. 10, 1913.

Note.—The investigations on which this paper is based were conducted under the direction of W. D. Hunter, in charge of Southern Field Crop Insect Investigations.

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the two forms to interbreed very readily, however, thus demonstrating their very close relationship.

The biology of this weevil as studied at Victoria has been discussed in two papers.[1]

In the spring of 1914 the writer was stationed near Tucson, Ariz., where he studied the Thurberia weevil and its host plant under their natural conditions. These studies consisted of biological investigations similar to those conducted in Texas as well as the consideration of the possible and probable economic importance of the weevil in the arid West. The economic phases of the problem have been dealt with in another report,[2] so they will be only very briefly mentioned in the present paper.

The principal object of this report is to afford a comparison of the life functions of the weevils as performed by: (1) Texas cotton weevils at Victoria, Tex.; (2) Arizona Thurberia weevils at Victoria, Tex.; and (3) Arizona Thurberia weevils in Arizona. The first two subjects have already been covered in the papers previously mentioned and the last is discussed in the present paper. By a proper consideration of the activity and adaptability of the different forms of weevils under the same environmental conditions and of the same form of weevil under the different conditions it is possible to determine much of importance concerning the exact relation of the two varieties and the extent of variation and adaptation to be expected from each.

For the Arizona studies a camp was established at the Agua Caliente Ranch, about 18 miles east of Tucson. This ranch is located in the foothills of the Santa Catalina Mountains, near the eastern end of the range, at about 2,800 feet elevation. The various breeding experiments described were conducted in this tent while the field tests were located on the near-by irrigated land. These studies were continued from April 16, 1914, to November 16, 1914.

DISTRIBUTION OF THE THURBERIA PLANT AND WEEVIL.

The weevil is not known to occur on any plant other than Thurberia in Arizona, and it seems so closely linked with this plant that every Thurberia plant may be considered as a potential host for the species even though all of these plants do not harbor weevils now. Consequently knowledge of the distribution of the plant is of great importance in the study of the weevil.

The distribution of the Thurberia plant is but imperfectly known at present. Explorations have been made in Arizona by Mr. Vernon Bailey, Prof. J. J. Thornber, Mr. O. F. Cook, Dr. A. W. Morrill, Mr.

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[1] Coad, B. R., and Pierce, W. D. Studies of the Arizona Thurberia weevil on cotton in Texas. *In* Proc. Ent. Soc. Wash., v. 16, no. 1, p. 23–27, Mar., 1914.

Coad, B. R. Recent studies of the Mexican Cotton Boll Weevil. U. S. Dept. Agr., Bul. 231, 34 p., Aug. 2, 1915.

[2] Coad, B. R. Relation of the Arizona Wild Cotton Weevil to Cotton Planting in the Arid West. U. S. Dept. Agr., Bul. 233, 12 p., 4 pl., May 27, 1915.

W. Dwight Pierce, Mr. E. A. Schwarz, and Mr. H. S. Barber, but the only data we have concerning the occurrence of the plant in Mexico are the records found with the specimens in the various herbaria.

The various explorations in Arizona have shown the plant to be present in the following localities: Santa Catalina, Santa Rita, Tanque Verde, Rincon, Mule Pass, Huachuca, Chiricahua, Superstition, Bradshaw, Dos Cabezos, and Dragoon Mountains, Globe, and Fish Canyon of the Salt River Valley. (Fig. 1.) So far the plant has not been located in any of the mountain ranges west of Tucson, but explorations have been conducted in only two or three of these and it is quite possible that it occurs there.

The writer is indebted to Mr. F. L. Lewton, of the Division of Textiles, United States National Museum, for a copy of the data on the specimens of this plant in the following herbaria: Gray Herbarium of Harvard University; Herbarium of the New York Botanic Garden; Columbian Herbarium, New York Botanic Garden; Herbarium of the Academy of Natural Sciences of Philadelphia; and the United States National Herbarium.

Many of the locality names noted on these are now obsolete and are very difficult to locate, but a general idea of the Mexican distribution of the plant may be secured. Fronteras, Oputo, Tunicachi, and Babusac, all in the State of Sonora, seem to indicate that the plant extends along the mountain ranges in the eastern part of this State and connects with the various localities noted in southwestern Chihuahua. From this point it seems to follow the ranges down at least as far as a point near Guadalajara, Jalisco, Mexico. This is the most southern record the writer has been able to discover.

So far the weevil has been found only in the Santa Catalina, Rincon, Santa Rita, Tanque Verde, and Dos Cabezos Mountains. Of these ranges the first four adjoin the Santa Cruz Valley, in which Tucson is located, and the last is near Bowie. In the examination of the plants found in the other ranges of the State, no signs of weevils were found but the distribution is certainly more general than that now known. Further explorations will probably demonstrate the presence of the weevils in other mountain ranges, at least in the southeastern part of the State.

We have no information concerning the presence of the weevil on Thurberia in Mexico, but the writer believes that it will be found extending all along the mountain chain through eastern Sonora, western and southwestern Chihuahua, and then probably connecting directly with the central Mexican territory in which the weevils live on cotton.

HABITAT OF PLANT AND WEEVIL.

The studies of the past season were confined to the mountains around Tucson and the most thoroughly worked of these was the Santa Catalina Range, where the local distribution of the plant and

weevil was studied in detail throughout the range. In this range the Thurberia plant was found, scatteringly but very generally, at altitudes ranging from about 2,600 to 7,000 feet. The writer, working

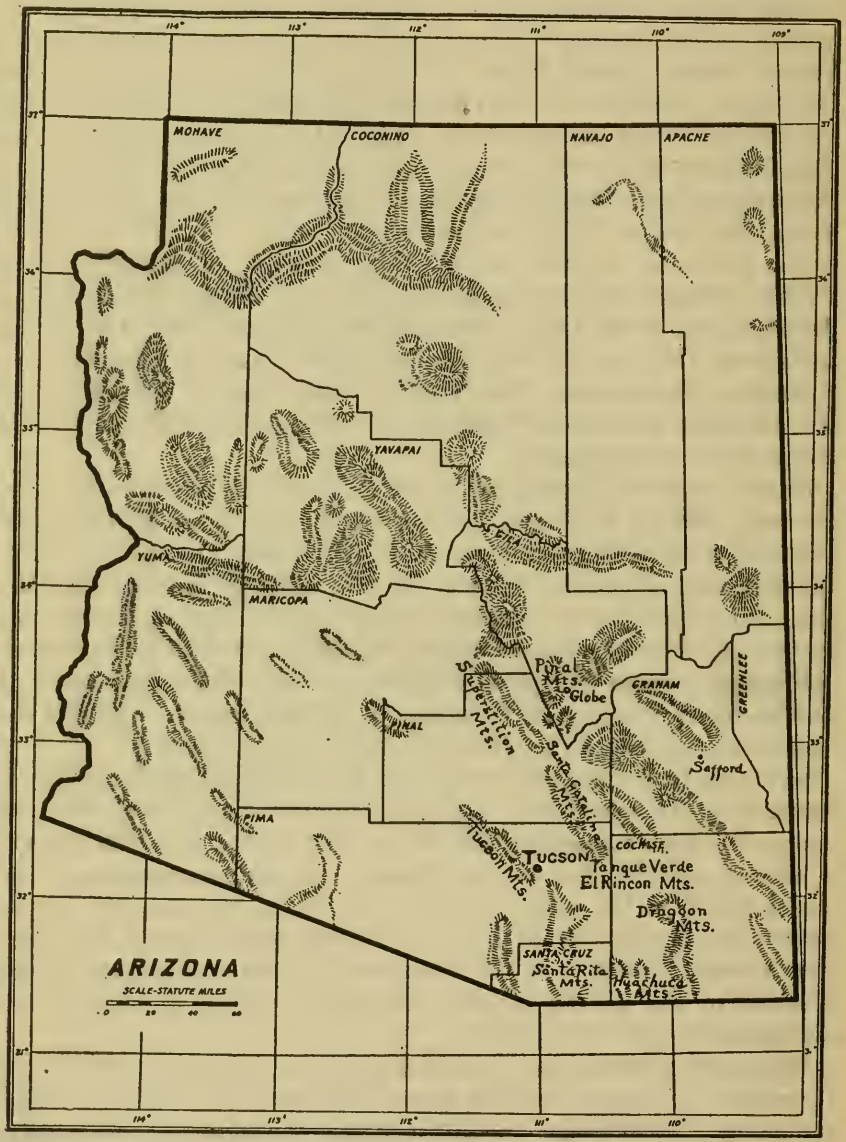

FIG. 1.—Map of Arizona showing mountain ranges representing the habitat of the Arizona wild cotton weevil (*Anthonomus grandis thurberiae*) and its food plant (*Thurberia thespesioides*). (Original.)

along the southern and southwestern slopes from the divide at the eastern end to the western tip of the range, practically circled the range. From the western tip of the range trips were made around the western end into the northwestern slopes at Montrose and Romero

FIG. 1.—DISPERSION OF THE WILD COTTON WEEVIL.

Typical location of Thurberia plant, below rock, in Agua Caliente Arroyo, Ariz., about 1½ miles from the mouth of the canyon. (Author's illustration.)

FIG. 2.—THE WILD COTTON WEEVIL AND ITS HOST PLANT IN THE LOWER RANGES.

Habitat of *Thurberia thespesioides* and the wild cotton weevil in the lower ranges. This view was taken in the Agua Caliente Arroyo, Ariz., about 100 yards below the plant shown in figure 1. (Author's illustration.)

THURBERIA THESPESIOIDES, THE FOOD PLANT OF THE ARIZONA WILD COTTON WEEVIL, ANTHONOMUS GRANDIS VAR. THURBERIÆ.

Canyons and nearly to Oracle. The writer then crossed the range by the trail above Agua Caliente Canyon, descended into the San Pedro Valley on the northeastern side, and explored the slopes. Combined with these observations numerous trips back and forth throughout the range were made at various points which gave comparatively thorough data on the internal conditions of the mountains.

Thurberia plants were found at intervals throughout this territory. Summarizing these observations it seems impossible to name any certain type of situation as the normal habitat of the Thurberia plant, since it is found in moist canyon beds, in dry arroyos, on dry slopes, and on the top of peaks. However, by far the greater number of plants are located in canyon beds, mountain washes, or arroyos out through the mesa, and in searching a new locality these are usually the most frequent situations in which the plant is found. Thurberia plants growing under these conditions usually develop a more healthy growth than those on the more exposed slopes, and usually the plants at higher altitudes, on slopes and peaks, are found more or less grouped in colonies. Travel for miles through such territory may not disclose a single plant when suddenly colonies of from three plants to several dozens are found. The distribution in canyon beds and washes, however, is quite different, for here the plants are usually found more or less scattered and growing singly, although in many canyons a plant will be found every few yards for several miles. (Pl. I, figs. 1, 2.) Occasionally, in locations particularly well sheltered from the force of the current, a large colony of plants may be found, but such cases are infrequent.

At lower altitudes, on the mesa and plains, Thurberia plants were found extending along the dry arroyos often to a distance of several miles from the base of the mountains. Here, while fairly common, they are scattered, being found along the margin of the channel, on small islands, or in protected situations behind rocks.

The occurrence of the Thurberia plant at an elevation of 7,000 feet was not noted until late in the season, at which time a few were found on a peak at about this elevation, behind Soldiers Canyon. It is interesting to note that one specimen in the Gray Herbarium and another in the Herbarium of the Academy of Sciences of Philadelphia, both collected by Edw. Palmer, bear the following data: "The Frailes above Batatopas, S. W. Chihuahua, Mexico, 7000 feet alt. October."

Back in the interior of the Santa Catalina range in the small canyons draining this country the plants were found to be quite common along the stream beds.

The Arizona wild-cotton weevil was found to be as widely distributed throughout this range as was the Thurberia plant, but the weevils were by no means present on all plants. While the weevils

were found in all types of situations at altitudes from about 2,750 feet to 7,000 feet, they were more abundant on plants growing at elevations of from 3,500 to 5,000 feet. The writer has been unable to determine any type of location as being especially favorable to the maintenance of the weevils.

In the Santa Rita Range the writer confined his studies almost entirely to points of less than 4,000 feet elevation. The country examined was that which lies along the base of the mountains commencing at a point below Madero Canyon and extending nearly to the northern end of the Santa Rita Range. Throughout most of this country the Thurberia plant was found extending down the arroyo nearly to the 3,000-foot level, and weevils were located on many of these plants at this elevation.

Very little exploring was done in the Tanque Verde Mountains, but a few trips were made on the northwestern slope above the village of Tanque Verde, where a few plants, some bearing weevils, were located in the "washes" of this comparatively regular slope.

In the Rincons the investigation was limited to the examination from the southern end of the range of some of the lower arroyos which form the headwaters of the Pantano, and Thurberia plants and a few weevils were found. Messrs. Barber and Schwarz found plants and weevils on the Manning trail above Mills ranch and Prof. Thornber reported a colony from a short distance above the Shaw ranch.

Investigation seems to have established that the Thurberia plant does not occur in the Tucson Range, as this range was explored by Dr. A. W. Morrill and Mr. W. Dwight Pierce during the summer of 1913 with negative results, and a search made by the writer in September, 1914, also proved negative. This range seems far too dry for the existence of the Thurberia plant.

SEASONAL ACTIVITY OF PLANT AND WEEVIL IN NATURE.

As the activity of the Arizona wild-cotton weevil in nature is largely dependent upon the growing and fruiting period of the plant, close observations were made, particularly in relation to the time of fruiting. These observations showed the time to vary greatly with the location of the plant, and the most important factor seems to be altitude and its accompanying conditions. The plants observed closely during this season ranged from 2,700 to 5,000 feet, and while no definite lines can be drawn, the following discussion gives the variations in time as they were noted at the different elevations.

Plants growing in the channels of Milagroso, Agua Caliente, and Soldiers Canyon and in the arroyos below these canyons (elevation below 3,000 feet) were all leafed out and squaring heavily by the 1st of May. They began blooming about May 7. After two or three weeks of flowering the buds ceased to appear and there was a

quiet period during which the bolls ripened, opened, and shed their seeds. Then another crop of buds appeared and the same course was repeated. In this manner as many as four crops of fruit were produced by some of these lower plants and many produced three.

Higher in the canyon channels and on the lower slopes (elevation 3,000 to 4,000 feet) the plants started to square shortly after the 1st of June and produced two or three crops before the end of the season. They all began leafing out about the same time as the lower plants just discussed.

About the 1st of July the plants growing at about 4,500 feet started squaring while those above 5,000 feet did not start until July 30 or later, and produced only one crop.

From this is seen the extreme variation in the fruiting period of the plant. This grouping by altitude is of course only approximate because the conditions (moisture, exposure, etc.) vary greatly at the same altitude in different locations.

The active period of the plant will probably vary with the different years according to climatic conditions. The winter of 1913–14 was exceptionally mild and consequently some of the lower plants may have started blooming earlier this season than is usual.

Regardless of the previous activity of the plants, the last crop of fruit (produced during August and September) is always the largest and blooming extends over a longer period at this time. Most of the plants stopped blooming during the latter part of September though quite a few continued blooming into early October.

The appearance of the weevils from hibernation is very scattering during the early spring months. The first record of emergence during the spring of 1914 was an individual noted in a branch of Agua Caliente Canyon at about 3,000 feet altitude on May 10. Following this a few were found active here and there in the mountains, but they were not common until later in the season.

These early individuals fed upon the squares and bolls present, and produced a few progeny in the latter. The resulting weevils emerged after a normal developmental period and aided in the infestation of the large crop of fruit in August and September.

The general emergence of the weevils began shortly after the first of July and by the middle of August nearly all weevils had emerged. These were all quite active on the plants after this time. During the past season the writer did not note a single weevil breeding in the buds of Thurberia, although considerable feeding upon them was observed. This is directly contrary to the conditions found by Mr. Pierce in August, 1913, when he observed the weevils breeding abundantly in Thurberia buds in both the Santa Catalina and Santa Rita Ranges. This discrepancy in records may be due to some differences in the seasonal conditions.

With the existing variations in time of emergence it is impossible to determine the exact number of generations per year, but most of the weevils seem to have only one or two, the last remaining in the pupal cells in the bolls and so hibernating.

The activity of the weevils seems to continue until stopped by the cold weather. It was greatly decreased in most places through October, but a few weevils were still active on the 1st of November.

EMERGENCE OF WEEVILS.

The study of the weevil activity in nature was greatly confused by the extreme variation in the time of emergence from hibernation. These weevils pass the winter in pupal cells in the Thurberia boll and, instead of emerging in the spring with the first warm weather, prolong the dormant period far into the season before leaving the cell. In fact, some individuals have been found in old cells as late as the 1st of September, though nearly all emerge during July and August. Because of the possible economic importance of this delayed emergence in relation to the transfer of the weevil from Thurberia to cotton, cage tests were conducted and careful observations made in the field to determine under what conditions the weevils will emerge.

For the cage tests a number of infested Thurberia bolls which had remained hanging on the plants since the fall of 1913 were collected in the upper part of Soldiers Canyon on June 6 and were kept in a dry box until the time of starting the tests.

The treatment of the different lots of infested bolls was as follows:

No. 1. Bolls not moistened placed in empty tumbler in shade.
No. 2. Bolls not moistened placed in empty tumbler in sun.
No. 3. Bolls not moistened placed on moist sand in shade.
No. 4. Bolls not moistened placed on moist sand in sun.
No. 5. Bolls immersed in water 1½ minutes and placed on moist sand in shade.
No. 6. Bolls immersed in water 1½ minutes and placed in empty tumbler in shade.
No. 7. Bolls immersed in water 30 minutes and placed on moist sand in shade.
No. 8. Bolls immersed in water 30 minutes and placed in dry tumbler in shade.
No. 9. Bolls immersed in water 30 minutes and placed on moist sand in sun.

These tests were started July 11, and each lot was examined at frequent intervals until September 22 and all emergence noted. Five bolls were placed in each lot. On September 22 all bolls were opened and the condition of the weevils inhabiting them noted.

From the unmoistened bolls placed in dry tumblers no weevils emerged. When the unmoistened bolls were placed on moist sand and left in the shade, two weevils emerged, but when they were placed in the sun none emerged. When the bolls were immersed in water for 1½ minutes and then placed on moist sand in the shade four emerged, but those moistened in the same manner and placed in a dry tumbler in the shade produced none. When immersed in water 30 minutes and left on moist sand in the tent three emerged and those moistened in the same manner and placed on moist sand

in the sun produced none. Those immersed 30 minutes and placed in a dry tumbler in the shade produced one weevil.

These results indicate the importance of moisture in the emergence of the weevils. Mere placing on moist sand caused some weevils to emerge in 5 days, but the bolls moistened and then placed on moist sand in the shade produced the maximum emergence. In the various lots which were placed in the sun not a single weevil emerged regardless of treatment. This was evidently due to the extreme heat in the tumbler. All weevils were found dead in these cells upon examination while many of those in the shade were still alive in the cells.

These experimental tests of the factors producing emergence are far from conclusive, but by combining them with various observations made in the field a fairly definite idea of conditions under which the weevils will emerge may be secured, and by studying the seasonal climatology of the region inhabited by the weevils it is possible to know when to expect the emergence.

The emergence of the weevil shows a very decided relation to the structure of the Thurberia boll and is the result of a gradual preparation of the boll which extends over a considerable period of time. In the fall the weevil cell is surrounded by the compact seeds and these in turn are inclosed in the covering of the boll. These soon dry and harden so that emergence is impossible. Then follows a slow changing of the boll extending through the winter months. The seeds around the cell ripen, harden, and separate slightly. The outer covering of the boll cracks apart at the apex and gradually splits toward the base. While this is largely a process of ripening and dessication, it is undoubtedly aided by the occasional rains during the winter and early spring. By spring the boll reaches a condition such that it is easily opened and the seeds scattered by a light crushing, but now the weevil cell itself holds the contents intact. In fact most of the uninfested bolls have opened wide by this time and the seeds have been blown and shaken out by the wind.

At this period it seems usually necessary for the boll to be at least slightly moistened to soften the cell before the weevil can emerge. The tests of the amount of moisture required to accomplish this show that it is variable and that very little is necessary in some cases.

That moistening is not always necessary to allow emergence is shown by the fact that the writer has observed weevils both in the field and in the laboratory emerging from perfectly dry bolls which had not been moistened for weeks. These cases seem to be due to the imperfect formation of the cell, which is weak enough to be broken by the drying of the boll and separation of the seeds.

From these observations concerning the importance of moisture in the emergence of the weevils, it seems quite probable that in the

vicinity of Tucson the normal emergence in the mountains is scattering during the spring and summer months, depending largely upon the frequence of the showers during this period, and that the general emergence is produced by the rains of July and August.

RELATIVE ATTRACTION OF COTTON AND THURBERIA FOR WEEVILS.

During the season a number of tests were made to determine the relative powers of cotton and Thurberia for attracting the weevils. Various types of weevils and different foods were used in the different lots but the method of procedure was identical for all.

Large, weevil-proof screen cages were used. They were placed on bare ground which was kept slightly moist by an irrigation ditch on each side of the row of cages.

In preparing the cage for the test the Thurberia plant was placed upright in one corner about a foot from the wall of the cage and the cotton plant was placed diagonally opposite. Then the weevils were released on the ground in the center of the cage. Following this, examinations were made frequently to determine the amount of feeding on each plant and the weevils present on each. All weevils found on plants were removed and released in the center of the cage. Fresh plants were placed in the cages almost every day or often enough to keep green food present at all times. In order to eliminate the influence of light from any selection the weevils might make, the positions of the plants were reversed daily.

All weevils were hibernated individuals which were removed from their 1913 pupal cells in Thurberia bolls. The observations may best be divided according to the food of the weevils before these were placed in the test cages.

WEEVILS NOT FED BEFORE TESTING.

On the 1st of August 14 males and 14 females removed from bolls collected in December, 1913, in the Santa Rita Mountains were placed immediately in a cage with cotton and Thurberia plants bearing neither squares nor bolls. On August 24 plants with squares and bolls were started and continued as the food for the remainder of the experiment.

Feeding began immediately on both plants and was continued more or less constantly until the close of the experiment on September 17. For the first 15 days the feeding was mostly on Thurberia, but after that time cotton was more or less favored. The summary of the observations for the entire period is as follows:

Cotton attacked	records..	24
Thurberia attacked	do....	16
Weevils on cotton, 3 male, 21 female	total..	24
Weevils on Thurberia: 3 male, 14 female, 2 of sex not determined	total..	19

From this it is seen that more weevils were observed on cotton and there was also more feeding on this plant than on Thurberia in the course of the entire experiment. At the very beginning what seemed to be a preference in favor of Thurberia was noted, but this disappeared later.

On the 4th of August 13 females and 12 males were removed from cells in Thurberia bolls collected in the Santa Rita Mountains in December, 1913, and kept almost entirely without food (cotton leaves fed only once) until August 7. They were then placed in a cage with Thurberia and cotton plants, both bearing buds and bolls. The experiment was continued until September 17 though the last feeding was noted September 11. Throughout this time a slight preference in favor of Thurberia was maintained and the summary of observations is as follows:

Cotton attacked	records..	7
Thurberia attacked	do....	13
Weevils on cotton, 3 male, 4 female, 1 of sex not determined	total..	8
Weevils on Thurberia: 7 male, 11 female, 1 of sex not determined	total..	19

These two tests of unfed weevils total as follows:

	Records.
Cotton attacked	31
Thurberia attacked	32
Weevils on cotton	32
Weevils on Thurberia	38

From these figures it is quite evidently useless to attempt to credit the weevils with a choice for either plant when unfed before testing.

WEEVILS FED UPON COTTON SQUARES BEFORE TESTING.

On the 24th of August 12 weevils of each sex were removed from the hibernation cells in Thurberia bolls collected in the Santa Rita Mountains December 4, 1913. These were fed upon cotton squares from this date until August 31 and then placed in a cage with cotton and Thurberia plants bearing buds and bolls. This test was continued until September 27 and the feeding continued until that date.

For the first few days a slight preference in favor of cotton was shown, but this soon disappeared and the feeding was much the same on the two plants for the remainder of the experimental period. The summary of observations is as follows:

Attacking cotton	records..	9
Attacking Thurberia	do....	7
Weevils on cotton: 8 male, 6 female, 1 sex not determined	total..	15
Weevils on Thurberia: 11 male, 6 female, 1 sex not determined	do...	18

From this feeding it is evident that, while the feeding upon cotton squares for the first few days after emergence may have caused a slight preference in favor of cotton plants early in the test, this did not last more than a very short time and then no preference was shown.

WEEVILS FED UPON THURBERIA BEFORE TESTING.

On August 24 another lot of weevils (11 males and 12 females) were removed from cells in Thurberia bolls collected in the Santa Rita Mountains December 4, 1913. These weevils were fed upon Thurberia buds and leaves until August 31 and then were placed in a cage with Thurberia and cotton plants, both bearing squares and bolls. Here the initial feeding showed a preference for Thurberia, but this was lost within a few days and the feeding became almost equal on the two plants. The test was continued until September 17 and feeding lasted until that time. The summary of observations for this lot is as follows:

Attacking cotton	records..	7
Attacking Thurberia	do....	6
Weevils on cotton: 5 male, 7 female	total..	12
Weevils on Thurberia: 7 male, 11 female	do....	18

SUMMARY OF ALL TESTS.

The summary of the results of the various experiments just detailed is given in Table I.

TABLE I.—*Relative attraction of cotton and Thurberia for weevils.*

Food before starting test.	Cotton.					Thurberia.				
	Plants attacked.	Weevils.				Plants attacked.	Weevils.			
		Male.	Female.	Sex not determined.	Total.		Male.	Female.	Sex not determined.	Total.
None	31	6	25	1	32	32	10	25	3	38
Cotton squares	9	8	6	1	15	7	11	6	1	18
Thurberia buds	7	5	7	.....	12	6	7	11	.....	18
Total	47	19	38	2	59	45	28	42	4	74

From this table it is seen that, while the cotton plants were attacked slightly more than the Thurberia, more weevils were observed on the latter. It is interesting to note that in the total of the observations of the weevils on both plants males were noted 47 times and females 80 times. As the weevils used were very nearly equally divided as to sex (49 males and 51 females), this seems an instance of the greater activity of the females.

These cage tests seem to indicate that unfed hibernated Thurberia weevils display no preference for either plant, while those fed on either plant exclusively for a few days after emergence will at first favor that plant slightly when offered a choice, but will soon feed equally on both. From this it would seem that neither plant has the power to attract the weevils away from the other, but later observations made in the field are rather contradictory to this. The field cotton at the ranch this season was repeatedly attacked by the weevils, and, while there was considerable injury to the squares and bolls on this cotton, only two bolls were attacked on

several Thurberia plants growing so close that some branches overlapped the cotton.

LIFE-HISTORY STUDIES.

FECUNDITY.

A number of series of Thurberia weevils were tested to determine the fecundity of the females on the different foods.

WEEVILS FED ON COTTON SQUARES.

During the season 14 pairs of weevils were mated on cotton squares in glass tumblers and the fecundity determined. These weevils either emerged from or were removed from their hibernation cells in Thurberia bolls collected at different points in the Santa Catalina and Santa Rita Mountains. They were all hibernated individuals. Nearly all were left on cotton squares until the close of the experiment, but two were removed from this food after 17 days and fed on cotton bolls for the remainder of the period.

Of the 14 females thus mated, 13 oviposited more or less normally. The other one, placed with cotton squares August 31, deposited one egg October 5 and another one October 7 and then stopped. This female was still alive and feeding at the close of the experiment on November 8. The data showing the activities of the 13 normal females are given in Table II.

Owing to the shorter active season to which the Arizona weevils are accustomed, it seemed quite probable that the average fecundity of the females would not equal that of the Texas weevils, but this is seen not to be the case. These averages secured with *thurberiae* on cotton squares in 1914 are very nearly as high as those from the best series of *grandis* reared in Texas on the same food in 1913, and they are higher than the general average of all series of *grandis*.

TABLE II.—*Fecundity of Anthonomus grandis thurberiae mated on cotton squares, Agua Caliente ranch, Arizona, 1914.*

Source of weevils.	Date first fed squares.	Date first egg.	Period fed squares to deposition.	Date last eggs.	Oviposition period.	Total eggs.	Average eggs per day.	Date female dead.	Date male dead.
			Days.						
Emerged from cells in Thurberia bolls	June 23	July 5	13	Aug. 10	36	176	4.9	Aug. 10	
Removed from cells in Thurberia bolls	June 25	July 15	20	Aug. 7	24	116	4.8	Aug. 7	
Do	July 8	July 12	4	Aug. 31	51	82	1.6	Sept. 14	July 12
Do	...do	July 13	5	Aug. 14	33	150	4.5	Aug. 11	Sept. 11
Do	...do	July 15	7	Aug. 19	36	126	3.5	Aug. 24	Aug. 14
Do	July 11	...do	4	Aug. 28	45	217	4.8	Aug. 30	Sept. 4
Do	...do	...do	4	Aug. 13	30	144	4.8	Aug. 14	Sept. 11
Do	Aug. 11	Aug. 21	10	Sept. 16	27	92	3.4	Sept. 19	
Do	...do	Aug. 20	9	Oct. 31	72	309	4.3		
Do	...do	Sept. 1	20	Nov. 2	62	299	4.8		
Do	Aug. 31	Sept. 12	12	Nov. 4	54	156	2.9		Oct. 31
Do[1]	...do	Sept. 7	7	...do	59	39	.7		Sept. 12
Do[1]	...do	Sept. 12	12	Oct. 19	38	141	3.7	Oct. 19	
Total			127		567	2,047			
Average			9.7		43.6	157.4	3.4		
Maximum			20		72	309	4.9		
Minimum			4		24	39	.7		

[1] These weevils were fed on squares until Sept. 17, and then on bolls.

The transfer of some of the weevils from cotton squares to cotton bolls late in life seemed to have no effect upon their oviposition as they continued ovipositing at about the same rate without a break.

It is interesting to compare the data presented in this table with the results secured by mating *thurberiae* on cotton squares in the same manner at Victoria, Tex., in 1913. Table III gives this comparison.

TABLE III.—*Comparison of results secured in Arizona and Texas with regard to fecundity of Anthonomus grandis thurberiae.*

	Average oviposition period.	Average eggs per female.	Average eggs per female. per day.	Maximum eggs per female.
	Days.			
Texas	32	103.0	3.2	173
Arizona	45.1	157.4	3.4	309

This table shows the greater fecundity of the variety under Arizona conditions than under the unnatural environment of southern Texas, although the daily rate of oviposition was much the same.

WEEVILS FED ON COTTON BOLLS.

Four pairs of hibernated *thurberiae* were removed from the cells in Thurberia bolls and mated on cotton bolls in glass tumblers in the same manner that others were mated on cotton squares. The results secured from these are shown in Table IV.

TABLE IV.—*Fecundity of Anthonomus grandis thurberiae on cotton bolls, Agua Caliente Ranch, Arizona, 1914.*

Source of weevils.	Date first fed bolls.	Date first egg.	Period fed bolls to deposition.	Date last egg.	Oviposition period.	Total eggs.	Average eggs per day.	Date female dead.	Date male dead.
Removed from cells in			*Days.*		*Days.*				
Thurberia bolls	July 13	July 20	7	Aug. 13	25	7	0.3	Aug. 24	July 19
Do	July 15	July 19	4	Aug. 10	22	64	2.9	Aug. 13	Aug. 17
Do	...do....	...do....	4	Aug. 17	29	84	2.9	Aug. 30	
Do	Aug. 11	Aug. 21	10	Oct. 14	55	190	3.4	Oct. 21	
Total			25		131	345			
Average			6.2		32.7	86.2	2.6		
Maximum			10		55	190	3.4		
Minimum			4		22	7	.3		

From this table it is seen that the weevils displayed a comparatively low degree of fecundity. This is seemingly in direct contradiction to the results secured in the series of weevils on live plants in the field and also of those offered a choice between cotton squares and bolls. Quite a number of tests in glass tumblers were made during the season to determine the preference displayed by the weevils in

relation to cotton bolls and squares. These all gave the same result, namely, that cotton bolls were much preferred to cotton squares. While there would always be some feeding upon the squares and an occasional egg would be deposited in them, by far the greater part of the feeding and deposition was on the bolls. In the field experiments where the weevils were placed on growing cotton plants there was some feeding on squares but the bolls received almost all of the feeding and deposition. In the breeding experiments where weevils were mated on squares for some time and then placed on bolls the oviposition continued through the change of food without diminution. In view of these observations it seems quite reasonable to believe that the cotton bolls are better suited to the weevil than the squares and hence it is hard to account for the much lower fecundity shown by the weevils in this boll-fed series than by those in the corresponding series fed upon squares.

WEEVILS FED ON THURBERIA.

At different times during the season weevils were removed from their hibernation cells in Thurberia bolls and mated in glass tumblers containing Thurberia leaves, squares, and bolls. For some reason these attempts to secure egg deposition were almost total failures. Nine pairs were mated in this manner and of these, seven females failed to deposit any eggs, one deposited a single egg, and the other deposited 66 eggs. This last female was placed with the food September 1, deposited the first egg September 23, and the last October 16, giving an oviposition period of 24 days. The average number of eggs per day was 2.7.

Some of the females which did not oviposit were allowed to live until their normal death, while others were killed after some weeks because of lack of food. It is difficult to determine the cause of this failure of the females to oviposit, but it is probably due to some fault in the breeding methods. One point which was noted in this connection was the extreme rapidity with which Thurberia bolls ripen after removal from the plant and hence become unfit for egg deposition. The seeds dry and harden very rapidly even though the boll is quite small. In such bolls the weevils will feed through the tender tissue near the stem end, but will not oviposit. The experimental conditions (cages, tumblers, etc.) were exactly the same as those for weevils upon cotton squares and bolls which were ovipositing normally at this same time, so the cause evidently was some fault with the condition of the food. Two females which were allowed to remain in tumblers with Thurberia bolls and squares for 14 days without oviposition were then transferred to living Thurberia plants in the field and they immediately began ovipositing.

DEVELOPMENTAL PERIOD.

IN COTTON SQUARES.

No observations were made on the length of the different immature stages in cotton squares, but the total developmental period was studied throughout the season from eggs deposited from July 6 to about the 1st of November. The squares were placed on moist sand in glass tumblers each day and the sand was kept damp. The date of the emergence of the adult was noted and the period between egg deposition and adult emergence was thus determined. However, this period was often not a true developmental period because it was found that, instead of emerging within a day or two after transforming to adult, as is the case with *grandis* in the Southern States, many of the weevils would remain in the cells for some days after becoming adult. This was particularly the case during the latter part of the season.

In watching for the emergence of adults each lot of squares was examined daily for about 20 days after egg deposition and then was examined only occasionally. In this way the dates of emergence were secured when the weevils emerged shortly after becoming adults, but late in the season many emerged after the daily observations had been stopped and consequently no figures were secured on their time of emergence. As this delayed emergence did not become usual with the weevils until those from eggs deposited after the 1st of September had developed, the data have been divided at this date and are given in Tables V and VI.

The figures in Table V are probably very nearly those for a developmental period such as is experienced by the Texas cotton boll weevils and the periods are surprisingly similar to those of cotton boll weevils. It is interesting to note that the average developmental period of both sexes of *thurberiae* in Arizona was 15.4 days while in southern Texas it was 18.5 days. It seems probable that nearly all of the weevils included in Table VI delayed emergence. This was probably due to the approach of the time for entering hibernation. From the squares receiving eggs before September 1, 71 weevils emerged in normal time and 2 were retarded, while from those receiving eggs after this date 10 emerged more or less normally and 48 were retarded.

In this series 1,260 squares containing eggs were observed and these produced 145 weevils, including those found in the cells. In other words, only 11.5 per cent of the squares receiving eggs produced adults. This is a very low percentage and seems to indicate that the cotton squares are not completely suited to the development of the Arizona weevil.

TABLE V.—*Developmental period of Anthonomus grandis thurberiae in cotton squares, Arizona, 1914; eggs deposited before Sept. 1.*

Date eggs deposited.	Date adults emerged.	Males.			Females.			Adult emerged but date not noted.	Stages found upon examination of squares.
		Period.	Number weevils.	Weevil days.[1]	Period.	Number weevils.	Weevil days.[1]		
		Days.			*Days.*				
July 6	July 24	18	1	18	.....	.....	.....	.....	
7	July 25	18	1	18	18	1	18	.....	
8	July 22	.....	.....	.....	14	1	14	.....	
9	July 23	14	1	14	14	2	28	.....	
9	July 24	15	1	15	.....	.....	.....	.....	
11	July 25	.....	.....	.....	14	1	14	.....	
11	July 26	.....	.....	.....	15	1	15	.....	
12	July 25	13	2	26	.....	.....	.....	.....	
12	July 28	16	1	16	.....	.....	.....	.....	
13	...do.....	15	1	15	.....	.....	.....	.....	
14	July 27	13	1	13	.....	.....	.....	.....	
14	July 28	.....	.....	.....	14	1	14	.....	
14	Aug. 1	.....	.....	.....	18	1	18	.....	
15	July 29	14	3	42	14	1	14	.....	1 adult died in cell without emerging.
15	July 30	15	1	15	15	1	15	.....	
15	Aug. 1	17	1	17	.....	.....	.....	.....	
16	July 29	13	1	13	.....	.....	.....	.....	
16	July 30	14	1	14	14	2	28	.....	Do.
16	Aug. 1	16	2	32	16	2	32	.....	
16	Aug. 4	18	2	36	.....	.....	.....	.....	
17	Aug. 1	15	2	30	15	3	45	.....	1 male dead.
18	...do.....	.....	.....	.....	14	3	42	.....	1 adult dead in cell.
18	Aug. 3	.....	.....	.....	16	1	16	.....	
19	Aug. 2	14	1	14	14	1	14	.....	
19	Aug. 3	.....	.....	.....	15	2	30	.....	
19	Aug. 4	.....	.....	.....	16	1	16	.....	
20	Aug. 3	14	1	14	14	2	28	.....	
23	Aug. 7	15	1	15	.....	.....	.....	.....	
23	Aug. 11	.....	.....	.....	19	1	19	.....	
24	Aug. 8	15	1	15	.....	.....	.....	.....	
24	Aug. 10	17	1	17	17	1	17	.....	
24	Aug. 13	20	1	20	.....	.....	.....	[2] 1	
25	Aug. 7	13	1	13	.....	.....	.....	.....	
25	Aug. 10	16	1	16	16	2	32	.....	
25	Aug. 12	.....	.....	.....	18	1	18	.....	
27	.....	.....	.....	.....	.....	.....	.....	[3] 1	
28	Aug. 12	15	1	15	.....	.....	.....	.....	
30	Aug. 17	18	1	18	.....	.....	.....	.....	
Aug. 1	...do.....	16	1	16	.....	.....	.....	.....	
1	Aug. 18	.....	.....	.....	17	1	17	.....	
2	Aug. 21	19	1	19	.....	.....	.....	.....	
3	Aug. 19	16	1	16	.....	.....	.....	.....	
3	Aug. 20	17	1	17	.....	.....	.....	.....	
11	Aug. 30	19	1	19	.....	.....	.....	.....	
28	Sept. 11	14	1	14	.....	.....	.....	.....	
Total.....		.....	38	592	.....	33	504	2	4.
Average.....		.....	.....	15.6	.....	.....	15.3	.....	
Total weevils of both sexes.		71						.....	
Average period for both sexes.		15.4						.....	

[1] "Weevil days" is the term applied to the sum of the time periods experienced by the various individuals during the course of the observations.
[2] Female.
[3] Male.

At the close of the experiment in November all squares were examined and the following stages were found remaining in them: 9 dead adults, 5 live adults, 7 live pupæ, and 12 live larvæ. The live adults were found only in squares receiving eggs after October 14, so it is quite possible that they would still have emerged. The immature stages were in the later lots of squares and probably had not had time to become adult.

TABLE VI.—*Developmental period of Anthonomus grandis thurberiae in cotton squares, Arizona, 1914; eggs deposited after Sept. 1.*

Date eggs deposited.	Date adults emerged.	Males.			Females.			Adult emerged but date not noted.	Stages found upon examination of squares.
		Period.	Number weevils.	Weevil days.	Period.	Number weevils.	Weevil days.		
		Days.			*Days.*				
Sept. 1								1 male	
2								1 female	
11								2 females	
12								3 males and 2 females.	
16								1 weevil	
17	Oct. 3	18	2	36	18	1	18		
19	Oct. 21	32	1	32				1 female	
21								2 males and 3 females.	1 female dead.
23								1 male and 2 females.	
29	Oct. 21	22	2	44	22	2	44	4 males and 1 female.	
Oct. 1	...do	20	1	20				1 male and 2 females.	
3	Oct. 22	19	1	19				3 females	
5								2 males and 4 females.	2 females and 1 male dead.
7								2 males and 1 female.	
9								1 male and 1 female	
12								1 weevil	
14								2 males and 3 females.	2 females and 1 male alive.
16								1 female	1 female alive.
19								1 male and 1 female	
21									1 teneral male, 4 pupæ, and 1 larva alive.
23									2 pupæ and 1 larva alive in cells Nov. 9.
26									1 pupa and 3 larvæ alive in cells Nov. 9.
28									2 larvæ alive in cells Nov. 9.
31									3 larvæ alive in cells Nov. 9.
Nov. 2									2 larvæ alive in cells Nov. 9.
Total			7	151		3	62		
Average				21.5			20.6		
Total weevils of both sexes.				10					
Average period, both sexes.				21.3					

In the examination of these squares a great number of the nonproducing ones were found to have the contents more or less eaten by weevil larvæ. These larvæ were evidently unable to survive upon this food. Of course the larval mortality is quite high in any breeding series of either *grandis* or *thurberiae* regardless of the food, but this is certainly higher than usual.

IN COTTON BOLLS.

The developmental period of the weevil in cotton bolls was studied in the same manner as that just described for cotton squares. The results of this series are given in Table VII.

TABLE VII.—*Developmental period of Anthonomus grandis thurberiae in cotton bolls, Agua Caliente ranch, Arizona, 1914.*

Date eggs deposited.	Date adults emerged.	Males.			Females.			Condition found at examination of bolls at close of experiment on Nov. 10, 1914.
		Period.	Number weevils.	Weevil days.	Period.	Number weevils.	Weevil days.	
		Days.			*Days.*			
July 13	July 30	17	1	17				
23								1 live female in cell, 2 dead larvæ.
24								1 live female, 2 pupæ, and 1 larva dead.
25								1 live and 1 dead adult in cells.
27	Aug. 17	21	1	21				1 dead adult in cell.
28								Do.
30								Do.[1]
Aug. 1								Do.[1]
2	Aug. 25	23	1	23				1 male has emerged.
4								1 dead adult in cell.[1]
7	Sept. 4				28	1	28	Do.[1]
13								1 live pupa in cell.
20	Sept. 7				18	1	18	
24								1 dead adult in cell.[1]
28								1 female emerged before Sept. 22.
30								3 dead adults in cells.
31								1 male alive and 1 female dead in cells.
Sept. 1	Sept. 22	21	1	21	21	1	21	1 female alive, 2 adults dead.
2								1 male alive in cell.
3								1 male emerged, 1 adult and pupa dead.
4								1 male alive in cell.
11								2 adults dead.
12								1 live female.
14								1 male has emerged.
17								1 male, 1 female emerged; 1 male alive.
19								2 adults alive, 2 adults dead.
21								3 males emerged, 1 male alive in cell.
23								2 males emerged, 3 adults alive in cell; 1 male dead in cell.
27								1 male emerged, 1 male and 1 female alive in cell, 1 male dead in cell.
29								2 males alive in cell.
Oct. 1								1 female emerged, 2 males and 1 female alive in cell, 1 larva alive in cell.
3								1 female emerged, 1 adult dead in cell.
5								3 weevils alive in cells.
7								2 adults alive in cells.
9								2 adults and 2 pupæ alive in cells.
12								2 adults alive in cells.
14								1 weevil and 1 larva alive.
16								4 pupæ and 1 larva alive in cell.
19								2 pupæ and 1 larva alive in cell.
Total			4	82		3	67	
Average				20.5			22.3	
Total weevils, both sexes				7				
Average period, both sexes				21.4				

[1] These adults were evidently killed by proliferation.

From this table it is seen that the results of rearings in cotton bolls differ very widely from those in cotton squares. The most marked difference is in the tendency exhibited by the weevils to remain in hibernation in the cells in the bolls. In fact, only seven weevils emerged directly after what might be termed a normal developmental period.

All bolls were retained, and at the close of the experiments on November 10 all were opened and the contents noted. This examination showed that 15 adults had emerged after observations were stopped, 33 adults were alive in cells, 22 adults were dead in cells, 9 pupæ were alive in cells, 4 larvæ were alive in cells, and 3 larvæ were dead in cells. Thus it is seen that 22 adults emerged, 33 remained alive in the cells, and 22 died in them.

The developmental period for the seven weevils which were observed at the time of emergence varied from 17 to 28 days, with an average of 21.4 days. In Texas the Thurberia weevils averaged 25 days in cotton bolls. They displayed the same tendency to delay emergence some days after maturity but did not attempt to hibernate in the cell as in Arizona.

Many of the records point to the great irregularity of the development in cotton bolls. In one case where the egg was deposited August 13 a live pupa was found in the boll on November 10, or a total of 58 days for incubation plus larval plus part of pupal period. In another case where the egg was deposited October 1 a live larva was found November 10, or a total of 40 days for incubation plus part of larval period. When it is remembered that under the same conditions adults were produced and emerged in as few as 17 days after egg deposition, these records are all the more striking.

The death of the adults due to proliferation is quite interesting. Five were found which were quite evidently killed by this agency. In these cases the weevils had formed more or less normal pupal cells, but the growth of the tissue broke these and pressed the adults to death. Of course, there was no way to determine how many of the immature stages were killed by this phenomenon, but the number was probably quite high.

IN THURBERIA BOLLS.

The Thurberia bolls containing eggs secured in the different series of weevils fed upon this food were placed on moist sand in tumblers and an attempt made to rear adults. In such tests the bolls were always as green and fresh as possible and were selected as seeming best adapted for larval food. Early in the investigation it was quite apparent that a single moistening of the sand in the tumbler would not suffice to keep the boll fit for larval food through the developmental period, so the sand was moistened frequently. In this way what seemed to be the best conditions for development were secured, but, in spite of this, the attempt was almost a total failure.

Thirty bolls containing many eggs deposited from June 30 to October 16 were observed, and only one weevil emerged from the entire lot. This was a male which emerged October 31 from a boll which had received an egg October 1, giving a total period from

FIG. 1.—CAGED THURBERIA PLANTS INFESTED WITH WEEVILS. (ORIGINAL.)

FIG. 2.—CAGES OVER COTTON PLANTS USED IN STUDIES ON WEEVIL ACTIVITY. (ORIGINAL.)

TYPES OF REARING CAGES SIMULATING NATURAL CONDITIONS, USED IN STUDIES ON THE BIOLOGY OF THE ARIZONA WILD COTTON WEEVIL.

deposition to adult emergence of 31 days. At the close of the experiment all bolls were opened and the contents examined. Almost all of them showed not the slightest signs of weevil larval work and only one weevil stage was found. This was a pupa found November 9 in a boll which received an egg October 14.

Thurberia buds were tested in the same manner several times during the season but always with negative results. In fact, it was found exceedingly difficult to induce the weevils to deposit in them.

TESTS OF CAGED WEEVILS ON GROWING PLANTS.

ON THURBERIA PLANTS.

In order to study the activities of the weevils upon Thurberia plants in the field, a large cage was arranged over a plant growing under cultivation at the ranch. (Pl. II, fig. 1.) The plant was nearly 5 feet tall and well laden with buds, blooms, and bolls.

Two male and two female weevils were removed from hibernation cells in the Thurberia bolls August 30 and fed upon Thurberia buds and leaves in captivity until September 14. They were then released in the cage with the growing Thurberia plant.

On September 17 two small buds had fallen to the ground with feeding punctures. On the 21st 6 small bolls, 3 buds, and 2 blooms had fallen, all fed upon by the weevils. Several of the fallen bolls and many still hanging on the plant contained egg punctures.

On October 2 it was noted that a very large proportion of the bolls of the plant had been punctured and many contained eggs or larvæ, but very few squares had been attacked.

The plant stopped blooming about October 10, and at this time many of the bolls had the purplish color characteristic of those infested. No bolls were on the ground, and a rather violent shaking of the plant failed to cause any to drop. On October 31 one male weevil was found active on the roof of the cage. A very careful examination of the plant and trash in the cage failed to reveal any other weevils. The infested bolls were still hanging on the plant.

On January 2, 1915, all bolls were removed from this plant and the cage examined for weevils. No adults, either alive or dead, were found in the trash or on the cage walls. All bolls were examined and the following contents noted: 271 bolls taken from the plant were examined; 123 were uninjured, 115 were injured but contained no weevil stages, 30 contained live adults, and 3 contained 1 dead larva, 1 dead pupa, and 1 dead adult, respectively. Eight bolls found on the ground were examined and 6 were found to show signs of weevil injury, but no stages were present. Of the total of 279 bolls examined, 154 had been injured more or less by the weevils, or an infestation of 55.2 per cent. This indicates what was certainly a great activity on the part of the two females.

The fact that while 154 bolls showed signs of weevil injury, only 30 (19.4 per cent) contained live adults on January 2, indicates a very high larval mortality. Most of the injured bolls containing no stages showed only one or two seeds eaten out by larvæ, though in some the injury was more extensive. Whether or not this high larval mortality is found in nature is open to doubt, but the cage conditions very closely approximated those under which the lower plants and weevils exist. This larval mortality may explain one puzzling point in connection with the interrelation of the Thurberia plant and weevil—that is, why the weevil does not multiply entirely out of proportion to the abundance of its very restricted host plant when the females are evidently so extremely prolific in egg deposition.

ON COTTON PLANTS.

In the same manner that these weevils were tested upon growing Thurberia plants, others were tested on growing cotton plants. Five cages, three large and two small, were placed over rows of plants about 16 inches tall. These plants were all bearing squares, blooms, and bolls. A general view of these cages is shown in Plate II, figure 2. All weevils were collected feeding on Thurberia in the Santa Rita Mountains September 25 and kept without food for four days.

The weevils were introduced into the various cages September 29. The small cages (Nos. 8 and 9) each received two males and two females while the large cages (Nos. 3, 6, and 7) each received four of each sex. Following the introduction of these weevils the cages were examined frequently until October 31. The following is a summary of the injured forms which fell from the plants during this period:

Cage No. 8, 11 small bolls.
Cage No. 9, 14 small bolls, 2 squares.
Cage No. 3, 22 small bolls, 2 squares, and 1 bloom.
Cage No. 6, 13 small bolls, 3 squares, and 1 bloom.
Cage No. 7, 18 small bolls, 1 square.

It is interesting to note that all the egg deposition was in the bolls. In fact there was only a comparatively small amount of feeding on the squares and little more on the blooms. For egg deposition the female seems to prefer bolls from about one-fourth to one-third grown. Some of the smallest of these drop from the plant when the larval injury becomes severe but nearly all remain hanging.

On October 31 a final examination of all cages was made. At this time the leaves and other trash piled in the cage was examined for hibernating adults and the plants were examined for active ones. One weevil was found active on the wall of a cage, one was feeding on a bloom, and one was dead inside the bracts of a boll. One male and one female, both dead, were found at the bottom of a pile of trash.

On January 2, 1915, all bolls were collected from the cages and examined for weevil injury or stages. The results are shown in Table VIII.

TABLE VIII.—*Weevil stages found in cotton bolls taken from caged plants, Jan. 2, 1915.*

Cage No.	Bolls.		Live weevil stages.			Dead weevil stages.		
	Not injured.	Injured but no weevil stages present.	Larvæ.	Pupæ.	Adults.	Larvæ.	Pupæ.	Adults.
9	15	1						
8	7	8						
3	11	16		2	3			
6	5	7	2	1	4		1	
7	6	2	1	1	6		1	
Total	44	34	3	4	13		2	

The fact that only two weevils had emerged, both from fallen bolls, indicated the strong adherence of the weevil to the cell hibernation habit, even when transferred to cotton. One of the weevils which had emerged was found active on the ground and, judging from its condition, it had emerged only a short time before collection. A comparison of the number of immature stages found in these cotton bolls with that found in Thurberia bolls in a similar cage test shows the retarded development under the unnatural conditions of a cotton boll.

PARASITES AND PREDATORY ENEMIES OF THE WEEVIL.

In the course of the season's investigations several hundred infested Thurberia bolls were collected at various points in the Santa Catalina and Santa Rita Mountains and the adult weevils were reared. In spite of the great number of these bolls which were utilized, not a single parasite emerged. Not a record of weevil parasitism was made by the writer during the entire season.

Only one case of predaceous insects attacking *thurberiae* was noted. On September 25 in the arroyo below Saw Mill Canyon, Santa Rita Mountains, at about 3,500 feet altitude, three Phymatidæ were observed feeding on adult weevils. These have been determined by Mr. Otto Heidemann as *Phymata erosa* var. *fasciata* Gray (one female) and *Macrocephalus inequalis* Champ. (two males). The latter of these was the more abundant at this time.

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L. O. HOWARD, Chief

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NOTES ON THE PREOVIPOSITION PERIOD OF THE HOUSE FLY, MUSCA DOMESTICA L.

By R. H. HUTCHISON, *Scientific Assistant.*

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INTRODUCTION.

During recent years a great deal of emphasis has been laid upon the use of flytraps as a means of reducing and controlling flies. The popularity of trapping is based not only on the immediate results obtained, but also upon the claim that many female flies will be caught before they have laid their first eggs, and that thus the possible number of future generations will be greatly reduced. For much the same reason it has been urged that trapping flies in the early spring is effective in reducing the number of future generations. An apparent justification for this method of control was found in the published records of experiments and observations indicating a rather long period of time between the emergence of the adult fly and the first deposition of eggs.

Entomologists have been aware that these methods of control were founded upon a rather meager scientific basis. Comparatively few accurate data have been published bearing upon the length of the preoviposition period. The necessity of more data on this phase of the life history of the house fly was clearly pointed out by Dr. L. O. Howard (1911), and upon his suggestion work along these lines was begun during the season of 1913. The work has been carried out under the general direction of Mr. W. D. Hunter. A few experiments on the preoviposition period were carried out by the writer during the season of 1913 at Arlington, Va., and others during the spring of

NOTE.—This paper is intended for entomologists and others who are interested in the extermination of house flies.

1914 at New Orleans, La., at which place Mr. T. E. Holloway rendered great assistance. During the summer of 1914 an extended series of experiments was carried out by Mr. A. W. J. Pomeroy. After the severance of his connection with the bureau at the end of October the experiments which he had under way were continued during the fall by Mr. J. L. Webb, and during the winter months the writer continued the work in the greenhouses of the Arlington experiment farm of the Bureau of Plant Industry.

METHODS USED IN THE PREOVIPOSITION EXPERIMENTS.

In the experiments to determine the length of the preoviposition period (i. e., the time between the emergence of the adult fly and the first deposition of eggs) laboratory-bred flies were used. The breeding was carried out in a systematic way, and several strains or "pure lines" were followed out through five or six generations. Most of the strains were started from a small number of larvæ or pupæ found in manure piles, and the first flies to emerge from material thus collected were used as the parents of the strain. In one case, however, a strain was started from a pair of flies taken in coitu on July 25, 1914. Eggs were deposited on August 2, and breeding of this strain was continued through six generations.

The adult flies were kept in small cages. A type of cage found very satisfactory for this work was 22 inches high by 12 inches square. The framework was of soft pine 1 inch square. The top, bottom, and three sides were covered with bronzed screen wire, 16 mesh per inch. The fourth side, or front of the cage, was covered with screen wire about 8 inches down from the top. Below this was a board about 8 inches wide, in which was cut an armhole 5 inches in diameter. A sleeve of closely-woven black cloth was tacked over this. Below the board was fitted a drawer 4 inches deep, in which food and material for deposition were kept. Cages of this size were easily and quickly handled, and any part of the interior of the cage could be easily reached through the armhole, the sleeve preventing the escape of any flies during manipulations. The sliding drawer at the bottom of the cage made it possible to remove the contents and examine them for eggs without permitting any flies to escape. These cages were kept on the shelves of a screened insectary and were protected from the direct rays of the sun most of the day, but were freely exposed to air currents and to the outdoor conditions of temperature and humidity.

Flies were transferred to these cages soon after emergence and supplied with food and media for oviposition. The cages were examined daily; any dead flies were removed and the sex noted at the time of removal. In this way at the end of the experiment the total number of males and females was summed up, and the length of life of each fly in the lot was known. The manure or other medium

was removed each day and examined carefully for eggs. Fresh horse manure was supplied each day, care being taken that the manure was not fly-blown before it was introduced into the cages. This was managed by taking fresh manure from the stables early in the morning and keeping it in covered cans until used, and then examining it before introducing it into the cages. During midsummer the additional precaution was taken of boiling the manure for one-half hour before it was put in the cages. When other media were used for oviposition the same precautions against previous infestation were taken. At the time of the daily examination of the cages, and at other times as opportunity offered, observations were made as to copulations. As a rule a regular routine of observations was followed out with each lot of flies as long as any of them remained alive. In a few cases, however, the flies were killed after the first deposition of eggs in order to provide cage space for the new lots of flies emerging.

When, upon examination of the cages, it was found that eggs had been deposited, these were transferred, together with the medium, to small breeding boxes. These breeding boxes were of wood and very tightly made so that no cracks offered a chance for the escape of migrating larvæ. Boxes of two sizes were used. When the number of eggs was small they were bred out in small boxes measuring 8 by 8 by 10 inches, and for larger lots boxes measuring 12 by 18 by 12 inches were used. In one end of these boxes was an armhole 5 or 6 inches in diameter. Tacked carefully over this was a sleeve of black cloth of close weave. This was kept tightly closed with a rubber band when not in use. The top of each box was covered with a glass plate. Thus any flies could be seen as soon as they emerged.

As soon after emergence as possible the flies were transferred from the breeding boxes to the cages described above. This was done by capturing them in vials introduced through the sleeve, or by connecting the armhole of the breeding box with that of the cage by means of a glass cylinder. When the breeding box was darkened the flies soon found their way into the cage through the cylinder. Sometimes the puparia were collected from a breeding box before any emergence had taken place and put into vials or pill boxes and covered with sand. These were put into cages until emergence had occurred. After the first lot of flies had emerged the remaining puparia were transferred to another cage to obtain a second lot, and so on until all had emerged.

THE PREOVIPOSITION PERIOD.

The preoviposition period was determined in some 70 experiments during the season of 1914. Table I summarizes the results of these experiments, most of which are based on Mr. Pomeroy's notes but which include also some experiments by Mr. Webb and the writer, carried out during the autumn and winter. They have been arranged in the table in the order of the increasing length of the period.

TABLE I.—*Preoviposition period of the house fly, Musca domestica.*

Lot number.	Food of larvæ.	Food of adults.	Number of adults in lot.		Date of emergence.	Preoviposition period.	Average mean temperature.	Longevity.		Remarks.
			Male.	Female.				Minimum.	Maximum.	
						Days.[1]	°*F.*	*Days.*	*Days.*	
1	Moist bran	Banana, water, manure	(?)	(?)	Aug. 18, 10.30 a. m., to Aug. 19, 9.30 a. m.	2½	82.5	.....	.....	
2	do	Banana, corn syrup, rotten potato.	(?)	(?)	Aug. 17, 3.30 p. m., to Aug. 18, 10.30 a. m.	3	82	.....	.....	All killed Aug. 24.
3	do	Banana, water, manure	(?)	(?)	Aug. 19, 9.30 a. m. to 4.15 p. m.	3	80.6	.....	.....	
4	Manure[2]	Banana, water, manure and bran.	4	3	July 14	3	79.2	.....	.....	
5	Moist bran	Corn syrup, water, manure	(?)	(?)	Aug. 17	4	82	7	22	
6	Manure one-half, bran one-half.	Corn syrup, water, rotten potato.	(?)	(?)	Aug. 19	4	79.4	6	(?)	
7	do	Brown sugar, water, manure.	11	5	Aug. 28	4	74.5	1	54	
8	Manure in compost heap.	Banana, water, manure	15	7	July 21, 12 m., to July 22, 2 p. m.	4	82.1	3	43	
9	Manure one-half, bran one-half.	White sugar, water, manure.	(?)	(?)	Aug. 29, 12 m., to Aug. 30, 11 a. m.	5	74.3	5	51	
10	Bread moistened with milk.	Banana, water, manure and bran.	(?)	(?)	July 20 to July 21, 1 p. m	5	81.6	6	38	
11	Manure in compost heap.	Banana, water, manure	3	6	July 21	5	81.6	3	(?)	2 males escaped.
12	(?)	Brown sugar, water, manure.	(?)	(?)	Aug. 31, 12 m., to Sept. 1, 12 m.	6	72	3	42	
13	Manure in compost heap.	Banana, beer, manure	(?)	(?)	June 22, 4 p. m., to June 23, 10 a. m.	6(?)	79.9	10	29(?)	
14	Manure	Banana, water, manure, rotten potato	(?)	(?)	Aug. 11	6	74.5	.....	.....	
15	Manure one-half, bran one-half.	Brown sugar, water, manure.	(?)	(?)	Aug. 29	6	74	2	52	
16	Manure one-half, crushed oats one-half.	do	14	4	Oct. 24 to Oct. 26	6	.....	5	26	In greenhouse. Fungus killed most of these flies.
17	Manure one-half, bran one-half.	Corn syrup, water, manure	(?)	(?)	Aug. 17, 12 m. to 3.30 p. m.	6	79.7	8	19+	
18	Manure	Banana, water, manure	(?)	(?)	Sept. 2	6	69.2	10	22+	
19	Manure in compost heap.	Bread, beer, manure	[3] 102		June 22, 4 p. m., to June 23, 10 a. m.	7	78.5	2	29	
20	Pig manure, bran mixture.	Banana, water, manure	63	41	July 24, 2.30 p. m., to July 25, 11.30 a. m.	8	72	.....	.....	All flies killed on Aug. 3.
21	Manure	Milk, bread, manure	[3] 40		June 22, 4 p. m., to June 23, 10 a. m.	8	78.4	3	25	

22	Manure one-half, bran one-half.	Corn syrup, water, manure.	205	191	Aug. 15, 12 m., to Aug. 17, 11.30 a. m.	9	78.5	8	27	
23	Manure one-half, crushed oats one-half.	Brown sugar, water, manure.	6	5	Oct. 1, 11 a. m., to Oct. 3, 4.15 p. m.	9	64	7	22	Experiment ended by fungus.
24	(?)	Banana, water, manure	(?)	(?)	Sept. 1, 2 p. m., to Sept. 2, 10 a. m.	9	67.7	3	(?)	
25	(?)	Grape juice, manure	8	5	Sept. 2, 10 a. m., to Sept. 3, 4 p. m.	9	65	3	(?)	
26	Manure	Sugar, water, manure	26	8(?)	July 23, 3.15 p. m., to July 24, 11 a. m.	10	73.2	1	24	
27	do	Brown sugar, water, fresh manure.	22	10	Oct. 1, 4 p. m., to Oct. 3, 11 a. m.	10	65.6	14	18	Fungus first developed on fourth day after emergence.
28	do	Bread, beer, water, manure.	[3] 93		June 23, 3 p. m., to June 24, 3 p. m.	10	68.3	4	(?)27	
29	Pig manure, bran mixture.	Banana, water, manure	24	22	Dec. 1, 12 m., to Dec. 2, 12 m.	10	61.3	5	12	These flies bred from puparia collected at Bethesda, Md., Nov. 13, 1914. Bred in insectary, adults kept in greenhouse.
30	Manure one-half, crushed oats one-half.	do	15	18	Nov. 7, 12 m., to Nov. 10, 12 m.	10	.....	10	16	In greenhouse. Fungus killed all these flies.
31	Manure	Banana, water, fresh manure.	(?)	(?)	Sept. 7	11	60.1	.....	.....	
32	do	Brown sugar, water, manure.	12	13	Oct. 6, 9 a. m., to Oct. 9, 4 p. m.	11	64.3	4	41	No food for adults from Oct. 6 to 9.
33	Manure in compost heap.	Banana, manure	[3] 42		June 21, 4 p. m., to June 22, 4 p. m.	11	76.6	2	26	
34	Manure	Brown sugar, water, fresh manure.	13	7	Oct. 6, 10 a. m., to Oct. 8, 11 a. m.	11	64.3	16	24	Fungus appeared on seventeenth day after emergence.
35	do	Brown sugar, water, manure.	110	73	Oct. 3, 2 p. m., to Oct. 5, 11 a. m.	11	64.7	5	40	
36	(?)	do	(?)	(?)	Oct. 2 to Oct. 3, 3.30 p. m.	11	65	13	26	
37	Manure	White sugar, beer, manure.	5	4	Sept. 3	12	62.2	19	32	
38	do	Grape juice, water, manure.	5	8	Sept. 3, 2 to 4.30 p. m.	12	62.2	7	19(?)	
39	Manure in compost heap.	Banana, water, manure	[3] 43		June 21, 4 p. m., to June 22, 4 p. m.	12	76	14	29	
40	do	do	12	7	do	12	76	7	24	
41	Manure	do	(?)	(?)	Sept. 2	12	62.6	2	21	2 males remaining on Sept. 24 were killed and experiment ended.
42	(?)	White sugar, water, manure.	(?)	(?)	Aug. 30, 12 m., to Aug. 31, 12 m.	12	66.6	(?)	35	
43	Fresh manure	Banana, water, manure	[3] 33		Jan. 27, 12 m., to Jan. 28, 1 p. m.	12	67.8	4	30+	In greenhouse.
44	do	Banana with manure	17	12	Feb. 6, 3 p. m., to Feb. 8, 11 a. m.	12	71.7	5	22	Do.
45	Manure one-half, crushed oats one-half.	Brown sugar, water, manure.	8	3	Sept. 29, 3 p. m., to Oct. 1, 11 a. m.	13	63.7	13	35+	Last fly (female) escaped Nov. 4.

[1] Approximate.

[2] The term "manure" means "horse manure" unless otherwise stated.

[3] Sex not determined.

TABLE I.—*Preoviposition period of the house fly, Musca domestica*—Continued.

Lot number.	Food of larvæ.	Food of adults.	Number of adults in lot.		Date of emergence.	Preoviposition period.	Average mean temperature.	Longevity.		Remarks.
			Male.	Female.				Minimum.	Maximum.	
						Days.[1]	°*F.*	*Days.*	*Days.*	
46	Manure one-half, bran one-half.	Corn sirup, water, bread, manure.	9	21	July 24, 1 p. m., to July 25, 11 a. m.	14	80	9	38	
47	Manure	Brown sugar, water, manure.	52	17	Sept. 22	14	61.2	6	35	
48	Manure one-half, crushed oats one-half.	do	16	7	Sept. 27, a. m., to Oct. 1, 2 p. m.	14	62	10	31	
49	Manure	Banana, water, manure	20	15	Sept. 25, 3 p. m., to Sept. 26, 3 p. m.	14	61.5	14	31	
50	Manure one-fourth, crushed oats three-fourths.	Brown sugar, water, manure.	97	59	Sept. 25	14	60.6	3	32	
51	Manure	Banana, water, manure	(?)	(?)	Sept. 7, 2 p. m., to Sept. 9, 12.30 p. m.	14	62.6	4	45	
52	Manure, previously boiled.	do	(?)	(?)	Sept. 8	14	62.5	4	36	
53	Manure	Brown sugar, manure, rotten potato.	8	8	Sept. 2, 4.30 p. m., to Sept. 3, 4 p. m.	14	62.5	1	46	
54	do	Brown sugar, water, manure.	(?)		Oct. 5, 9 a. m., to Oct. 6, 12 m.	14	62.3	8	31+	Mice destroyed flies or permitted them to escape on thirty-first day.
55	Manure one-fourth, crushed oats three-fourths.	do	17	20	Sept. 26 to Oct. 1, 3 p. m.	15	66.7	9	24	No food for adults before Oct. 1, 3 p. m.
56	Manure one-half, crushed oats one-half.	do	80+	91+	Sept. 25, 2.30 p. m., to Sept. 26, 3 p. m.	16	62.5	2	51	
57	Bran-pig manure mixture.	Corn sirup, bread, manure	18	13	July 24, 1 p. m., to July 25, 11 a. m.	16	75.2	10	40 (?)	
58	Manure	Brown sugar, water, manure.	? 6	? 2	Oct. 15 to Oct. 21, 1. p. m.	16	.....	9	32	Cage started Oct. 21. Kept in greenhouse.
59	do	Grape juice, fresh manure	(?)	(?)	Sept. 2, 4.30 p. m., to Sept. 3, 3.30 p. m.	17	63	2	21	
60	do	Banana, water, manure	21	10	Sept. 5, 12 m., to Sept. 7, 2 p. m.	17	64.1	8	43	
61	do	Brown sugar, water, manure.	94+	34+	Sept. 22, 3 p. m., to Sept. 23, 4 p. m.	17	61.6	5	31+	Last male killed Oct. 24.
62	Manure one-fourth, crushed oats three-fourths.	White sugar, water, manure.	21	13	Sept. 24	17	61.5	1	36	

63	.....	Brown sugar, water, manure.	(?)	(?)	Aug. 6 to Aug. 7, 11 a. m.	17	78.7	1	(?)		
64	Manure.....	Banana, water, manure.....	(?)	(?)	Sept. 25, 8 a. m., to Sept. 26, 2 p. m.	18	59.1	13	29	Fungus killed numbers in latter part of experiment.	
65	.....do.....	Brown sugar, water, manure.	6	8	Oct. 4.....	19	63	19	30	Oct. 23 was latest date on which eggs were obtained in these experiments under outd oor conditions.	
66	Manure one-half, crushed oats one-half.	.....do.....	67	50	Sept. 24.....	19	61.7	4	40		
67	Manure.....	.....do.....	.....	.....	Sept. 22.....	20	63.5	3	42		
68	.....do.....	White sugar, water, manure.	16	9	Sept. 24.....	22	61	4	40		
69	.....do.....	White sugar, vanilla extract, manure.	7	6	Sept. 2.....	23	65.1	6	41		

[1] Approximate.

TABLE II.—*Preoviposition period of the house fly; tests with isolated pairs.*

No.	Food of larvæ.	Food of adults.	Date of emergence.	Taken in coitu.	Emergence to copulation.	Copulation to oviposition.	Total preoviposition period.	Average mean temperature.	Number of depositions.	Number of eggs per deposition.		Longevity of—		Remarks.
										First.	Second.	Male.	Female.	
					Days.	*Days.*	*Days.*	° *F.*				*Days.*	*Days.*	
1	Manure.....	Corn sirup, water, manure.	Aug. 11...	Aug. 14, 2.30 p. m..	3	6	9	71.2	2	30	40	(1)	(1)	
2	.....do.....	Banana, water, manure.	...do.....	.....do.....	3	6	9	71.2	1	96	.....	6	13	
3	.....do.....	.....do.....	...do.....	Aug. 14, 11.30 a. m.	3	6	9	71.2	1	25	.....	18	21	
4	.....do.....	.....do.....	...do.....	.....do.....	3	6	9	71.2	2	33	77	14	15	
5	Pig manure, bran mixture.	.....do.....	July 24, 2.30 p. m., to July 25, 11.30 a.m.	July 31, 10.40 a. m.	6	3	9	73.7	1	87	.....	13	[2] (?)	No records of female after Aug. 7.
6	Manure.....	Sugar, bread, water, manure.	July 23, 3.15 p. m., to July 24, 11 a. m.	July 28, 2.30 p. m..	4	5	9	72.9	1	28	.....	10	[2] (?)	Do.
7	(?)	Banana, water, manure.	(?)	July 26, 2.30 p. m..	(?)	8	(?)	72	1	40	.....	[3] 4	[3] 14	

[1] At least 16.

[2] At least 13.

[3] Days after copulation.

Many attempts were made by Mr. Pomeroy to keep isolated pairs of flies under as natural conditions as possible in order to obtain not only the preoviposition period but also the number of depositions per fly and the number of eggs per deposition. The usual method was to remove from a lot of laboratory bred flies the first pair which were found in copulation. After transfer to a separate cage they were supplied with food and a medium for oviposition and were kept under observation in much the same way as the larger lots. The results of the tests with isolated pairs are summarized in Table II.

The fact that only 7 out of some 30 tests gave any positive results points to the difficulties in obtaining significant data from experiments performed under artificial conditions.

The shortest preoviposition period was about two and one-half days (Table I, lot No. 1). Mr. Pomeroy's original notes on this lot show that the "flies emerged some time between August 18, 10.30 a. m., and August 19, 9.30 a. m.," at which time they were "transferred to cage and supplied with banana, water, and fresh manure. Examined August 20 at 3.30 p. m. No eggs were found. Fresh manure supplied. August 21, at 1 p. m., two clusters of eggs were found, 80 to 90 eggs in each cluster." Now, if the flies which deposited these eggs had emerged on the afternoon of the 18th the preoviposition period was a little longer than two and one-half days. If they had emerged during the morning of the 19th before 9.30 a. m. the period was a little less than two and one-half days. Other remarkably short periods are to be found in the three 3-day periods shown in the table, and in the four 4-day records. It is reasonable to suppose that if these short periods were found under artificial experimental conditions they would be not at all uncommon under natural conditions.

The longest period was one of 23 days (Table I, lot No. 69). In general it may be said that the shortest records occurred in midsummer and that the longer ones were obtained during the autumn months. It is true that some long periods were found in summer, e. g., a 14-day and a 16-day record in July, but no short records were ever found during the autumn months. In other words, the length of the preoviposition period is greatly influenced by the temperature. A study of Table I will show that the arrangement according to the increasing length of the period corresponds in a rough way with the order of the decreasing mean temperatures of those periods. The relation between the temperature and the length of the preoviposition period is made clearer in the correlation table (Table III), in which the columns give the preoviposition period in days and the rows represent 2° intervals of temperature.

TABLE III.—*Correlation between the average mean temperature and the length of the preoviposition period of the house fly.*

Average mean temperatures in 2° intervals.	Length of the preoviposition period in days.																				
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
82° to 84°	1		1																			
80° to 82°		2	1	2									1									
78° to 80°		1	1		2	1	1	1								1						
76° to 78°										1												
74° to 76°			1	1							2				1							
72° to 74°					3		1	2	1													
70° to 72°								4			1											
68° to 70°					1				1													
66° to 68°								1			2			1								
64° to 66°								2	1	4						1						1
62° to 64°												1	4		1	1		1	1			
60° to 62°										1	3		4			2		1			1	
58° to 60°																	1					

To represent this relation graphically the average of the average mean temperatures for all the records of a given length has been taken, and the following figures obtained:

Length of period.	Number of records.	Average of the average mean temperatures.
Days.		° *F.*
$2\frac{1}{2}$	1	82.5
3	3	80.9
4	4	79.5
5	3	79.2
6	6	74.9
7	1	78.5
8	2	75.2
9	10	71.2
10	4	67.1
11	6	65.8
12	8	68.1
13	1	67.3
14	9	63.9
15	1	66.7
16	2	68.8
17	5	65.8
18	1	59.1
19	2	62.3
20	1	63.5
22	1	61
23	1	65.1

Figure 1 shows the curve obtained by plotting these figures. The broken line in the figure is the hyperbole which is the nearest approach to the actual experimental curve. If it is true that "the curve expressing the increase in rate of development is a true hyperbole" (Pearls, 1914), one must seek for an explanation of the many deviations from the true curve which are seen in the experimental curve. It is of course probable that if the accumulated effective temperature for each period were worked out, the resulting curve would show a much closer approach to a true hyperbole.

It is not necessary to point out that there were several other variables among the conditions of these experiments. For example, humidity is no doubt an important factor, but the lack of complete and accurate records of the relative humidity prevents making any statistical analysis of its influence on the length of the preoviposition period.

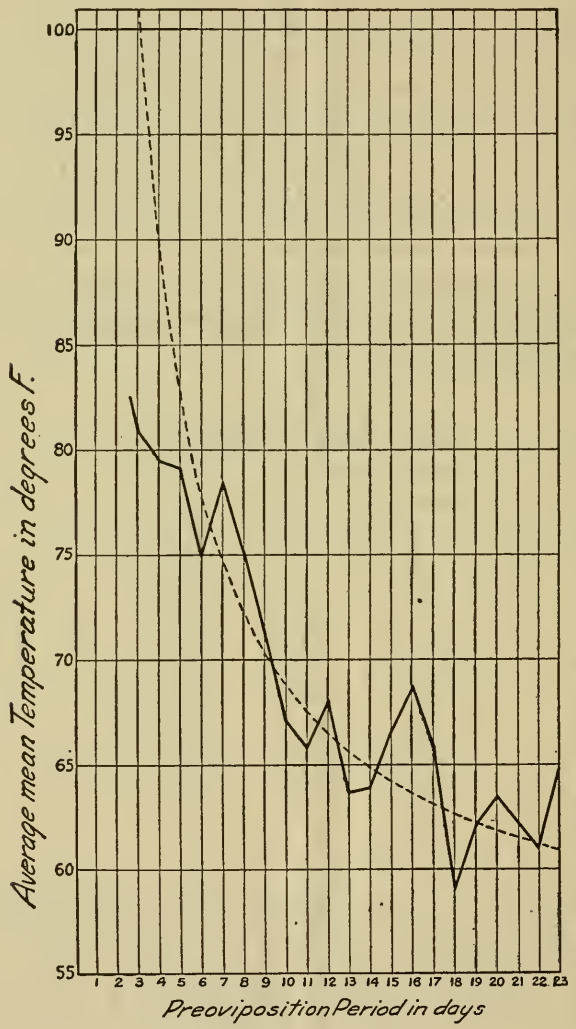

FIG. 1.—Curve showing correlation between the average mean temperature and the length of the preoviposition period of the house fly. (Original.)

It is interesting to note that Bishopp, Dove, and Parman (1915), in experiments at Dallas, Tex., obtained a 4-day record at an average mean temperature of 87.5° F., while the 4-day records at Arlington, Va., averaged 79.5° F. This and other differences between their results and those recorded in the present paper may in large part be due to the differences in the relative humidity of the two localities.

Bishopp, Dove, and Parman are doubtless correct in saying that in general "increased humidity seems to hasten egg laying."

The present results agree also with the Dallas observations in showing that the food supply of the adult flies has an important influence on the length of the preoviposition period. Banana, water, and manure was found to be a favorable combination in these experiments. Lack of moisture always proved fatal to flies, and without food they die within two or three days.

Yet temperature, humidity, and food supply are not the only factors which influence egg laying. If Table I be examined, such apparently contradictory results as an 8-day record at an average mean temperature of 72° F. (see No. 20) and a 12-day record at an average mean temperature of 76° F. (see No. 39) will be found. Mr. Pomeroy has suggested, and the writer is strongly of the opinion, that the kind and quality of the larval food is partly responsible for such apparent discrepancies. It is a well-known fact that the amount and kind of larval food have a marked influence on the size of the resulting adult flies, and there is no reason to doubt that the physiological activities of the adult are likewise affected. It appears in Table I that most of the shorter preoviposition records were obtained with flies which had been bred from larvæ fed on moist bran or a bran-manure mixture. From media which fermented less actively than these, or which were allowed to dry out, or were too small in quantity, the resulting flies were not only small but often failed to oviposit at all and usually lived a shorter time than large flies under the same conditions. Some larvæ bred exclusively on rotten potato produced a small race of flies which did not oviposit, due perhaps to the preponderance of starch in their diet. Griffith (1908) observes that small flies are incapable of reproduction.

In the experiments with isolated pairs of flies only 7 out of 30, or about 24 per cent, gave any positive results as regards the deposition of eggs. In the other experiments where a number of flies (8 to 200) were used in each lot, 70 out of 110, or about 63 per cent, gave positive results. It is possible that this may be accounted for by what may be called a psychological factor. The habit of the adult females of associating in large numbers in one favored spot in depositing eggs has been previously pointed out (Bishopp, Dove, and Parman, 1915), and it is probable that the isolation of a pair of flies is an abnormal condition which has its inhibiting effect.

As regards the number of depositions, the Arlington observations again agree with those made at Dallas in that it was impossible to obtain more than two lots of eggs from a single female, but this does not prove, of course, that under normal conditions the adult fly can not oviposit oftener. Griffith (1908) gives no details of experiments

or observations in support of his statement that the fly repeats the process of egg laying at intervals of 10 to 14 days till four batches have been laid. The largest number of eggs per deposition in these experiments was 96 and the smallest 25.

Recent experiments have placed the knowledge of the preoviposition period on a more complete basis and have shown that the period is considerably shorter than was previously thought to be the case. Dr. C. G. Hewitt publishes the results of experiments performed by him in England in 1907, in which the period was found to be 14 days. Griffith (1908) states that the adult fly can begin to lay eggs 10 days after emergence. Bogdanow (1903) publishes the results of some breeding experiments with the house fly. In a table given in his article it appears that in one experiment the first flies emerged on August 12 and the first eggs laid by these flies were found on August 18—a preoviposition period of 6 days.

COPULATION.

Observations on the copulation of flies were necessarily not continuous, but of chance observations there were a large number, and they show that copulation may occur as early as one day after emergence. There are three records of copulations taking place on the second day after emergence, and 14 records of copulations on the third day after emergence. The greatest number of records fall on the third to sixth days, inclusive. Copulations were observed as late as the twenty-sixth day, and in an experiment during the winter, when a lot of flies was kept in a stable where the air temperature ranged from 30° to 60° F., one copulation was observed on the forty-seventh day after emergence. The air temperature at the time was 55° F. During the autumn a number of copulations were observed taking place when the air temperature was 55° F., but no sexual activity was ever seen at temperatures lower than 55°.

LONGEVITY.

As stated, the daily routine of observations on the various lots of flies included the removal of dead flies and the recording of their sex and length of life. The experiments during the summer and fall of 1914 include records of some 3,000 flies. The longevity of these flies varied from 1 day to 54 days. The arithmetical mean of all these records was found to be 19+ days. This may perhaps be taken as the average for both sexes at all seasons. In midsummer the length of life is often much less and during the spring and autumn months is considerably more. In one hibernation experiment, in which flies were kept in a stable at temperatures varying from 30° to 60° F., a few lived as long as 70 days. This record was not included in calculating the mean longevity.

SUMMARY.

From the experiments reported in this paper it is seen that the shortest record for the preoviposition period was one of about 2½ days and the longest, one of 23 days, with most of the records falling on the fourth, fifth, sixth, ninth, twelfth, and fourteenth days after emergence.

It is shown that the temperature has a very decided influence on the length of the period.

Other factors influencing this period are humidity, the kind and quality of the food of the adults, and the kind and quality of the larval food with its resulting effect on the size and physiological condition of the adults. In the experiments with isolated pairs of flies very few results were obtained, which suggests that the association of a number of females in the process of egg laying is the normal habit and that isolation has an inhibiting effect.

Copulations were observed as early as the first day after emergence and as late as the forty-seventh day. No copulations have been noted when the air temperature has been below 55° F.

The maximum record for longevity was 70 days, and the minimum was one day or less. The average of the records of some 3,000 flies was slightly over 19 days.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 351

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER April 22, 1916

THE TERRAPIN SCALE: AN IMPORTANT INSECT ENEMY OF PEACH ORCHARDS

By

F. L. SIMANTON, Entomological Assistant, Deciduous Fruit Insect Investigations

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INTRODUCTION.

For several years the terrapin scale, *Eulecaniu mnigrofasciatum* Pergande, has been increasing in abundance in certain localities in the eastern United States, and complaints have recently come to the Bureau of Entomology from orchardists in numerous localities within the Appalachian peach belt of severe injury to peaches, and of inability to control the insect with the materials commonly used.

In order to investigate the insect under favorable conditions the Office of Deciduous Fruit Insect Investigations of the Bureau of Entomology maintained a field laboratory during the seasons of 1912 and 1913 at Mont Alto, Pa., which is well within the limits of the badly infested area. The following pages contain a record of the life-history studies made, together with a short historical account of the species. A detailed account is also given of its habits and of the remedies that have been devised for its control.

The author wishes to acknowledge the assistance of Dr. A. L. Quaintance, under whose direction this investigation was conducted, and to thank Messrs. D. M. Wertz and Aaron Newcomer for the use of their orchards and spraying machinery.

[1] *Eulecanium nigrofasciatum* Pergande.

HISTORY.

The terrapin scale, *Eulecanium nigrofasciatum* Pergande, is a native species which came to the notice of economic entomologists about 1870. Mr. Theodore Pergande, of the Bureau of Entomology, observed it as early as 1872. It was then believed to be the European scale *Lecanium persicae* Fab., an insect of similar habits. The publications prior to 1898, for the most part, refer to it under the latter name. Miss Mary E. Murtfeldt was the first writer to treat of this insect at any length. She observed it in 1893, at Kirkwood, Mo., but did not completely work out its life history. Her observations are recorded in Bulletin 32 [old series] of the Division of Entomology, United States Department of Agriculture (1893), under the name *Lecanium persicae* Fab.

Dr. L. O. Howard treated this species in the Yearbook of the United States Department of Agriculture for 1894 under the name *Lecanium persicae* Modeer, and there figured it for the first time.

Mr. Theodore Pergande became convinced that this lecanium was distinct from *L. persicae* Fab., and described it in Bulletin 18 [new series], Division of Entomology, United States Department of Agriculture (1898), as *Lecanium nigrofasciatum*, new species.

Since about 1898 the terrapin scale has gradually assumed more and more importance as an enemy of the peach, until now it is feared by the peach growers of Maryland and Pennsylvania more than any other species of scale insect. Most of the States east of the one hundredth meridian have mentioned this pest in their entomological publications during the last 10 years. At the present time it appears to be most abundant in portions of Maryland and Pennsylvania.

DISTRIBUTION.

There are no indications that the terrapin scale occurs outside of North America. It is at present, for the most part, confined to the humid area of the Austral Region, but there is danger that it may ultimately invade western peach orchards, especially those in the Austral Zones. This species has been taken in New Mexico and is doubtfully reported from southwestern Colorado, but, so far as known, it does not now occur in the other Western States. It has a slight foothold in Ontario Province, Canada, mostly upon maple. At the present time considerably more than one-half of all the known infestations are found in Pennsylvania and Maryland. (See fig. 1.)

In general this scale has advanced into the region of its principal food plants, having spread through the peach belt of the Eastern United States, and progressed northward beyond this belt by attacking ornamental trees, of which the maples and sycamores seem to be its favorite hosts. It has also extended its range in the Southwest

by attacking the mistletoe, upon which it thrives very well. It will undoubtedly spread considerably beyond its present range by advancing farther into the territory of its chief host plants. Those regions in which the peach, the plum, the maple, the sycamore, and the mistletoe are abundant probably offer suitable conditions for its growth.

ECONOMIC IMPORTANCE.

The terrapin scale, in its range and importance, ranks easily as second among the scale pests of the peach, and while not so prolific and not so injurious as the San Jose scale, *Aspidiotus perniciosus*

FIG. 1.—Distribution in the United States of the terrapin scale (*Eulecanium nigrofasciatum*). (Original.)

Comstock, it is even more of a nuisance, owing to the difficulty met with in its control.

INJURY.

This insect causes injury first, by sucking the sap from the trees, and second, by covering the fruit, leaves, and branches with a sweet sticky fluid known as honeydew.

The injury to the trees from the loss of sap taken by the scale is considerable in badly infested orchards, but is small in comparison with the damage resulting from the deposit of honeydew. This deposit, while objectionable, would not cause serious injury were it not for a black or sooty fungus which grows abundantly in the honeydew whenever this is present. On trees which are badly infested with the scale the fruit soon becomes covered with a black sticky coat which makes it almost unsalable, as it is nearly all classed as culls and is sold accordingly.

FOOD PLANTS.

Eulecanium nigrofasciatum attacks more than 30 species of plants. It becomes abundant, however, upon only a comparatively few of these. Its preference for its principal food plants is about in the following order: Peach, plum, maple, cherry, sycamore, mistletoe.

The following list includes all of the host plants known to the author:

Acer pscudoplatanus L. Sycamore maple.
Acer saccharinum L. Silver maple.
Acer saccharum Marsh. Sugar or rock maple.
Amygdalus persica L. and var. Peach and nectarine.
Benzoin aestivale (L.) Nees. Spice-bush.
Betula sp. Birch.
Bumelia angustifolia Nutt. Saffron plum.
Castanea dentata (Marsh.) Borkh. Chestnut.
Cercis canadensis L. Red-bud.
Chaenomeles japonica Lindl. Japan quince.
Clematis sp. Clematis.
Crataegus oxyacantha L. Hawthorn.
Crataegus. Most species.
Cydonia oblonga Mill. Quince.
Elacagnus angustifolia L. Oleaster.
Euonymus atropurpureus Jacq. Wahoo or burning bush.
Fraxinus sp. Ash.
Ilex opaca Ait. American or white holly.
Magnolia virginiana L. Sweet bay.
Melia azedarach L. Wild China-tree.
Morus spp. Mulberry.
Nerium oleander L. Oleander. Rose bay.
Ollea sp. Olive.
Padus sp. Wild cherry.
Phoradendron sp. Mistletoe.
Platanus occidentalis L. Sycamore or plane-tree.
Platanus orientalis L. European plane-tree.
Populus deltoides Marsh. Cottonwood.
Prunus sinconii Carr. Simon or apricot plum.
Prunus spp. Cultivated and wild cherries and plums.
Pyrus communis L. Pear.
Pyrus malus (L.) Britton. Apple.
Quercus virginiana Mill. Live oak.
Ribes sp. Gooseberry.
Rosa spp. Roses.
Salix babylonica L. Weeping willow.
Salix spp. Willows.
Sapindus marginatus Willd. Soapberry.
Tilia sp. Linden or basswood.
Umbelliferæ. One species.
Vaccinium spp. Blueberries.
Vitis vinifera L. European grape.
Vitis spp.

LIFE HISTORY.

MATURING OF FEMALES IN SPRING.

Hibernation is terminated by weather conditions. The conditions that cause the peach buds to open also bring this lecanium to the end of hibernation. At Mont Alto, Pa., in 1913, hibernation ended about April 1, at which time many blossoms were ready to burst. From April 1 to May 1 growth was rapid. From May 1 to May 16 it was comparatively slow. At the latter date the advanced females reached their maximum size, which they retained until the period of reproduction was nearly over. All the females had reached maturity by June 10. Table I shows the minimum, maximum, and average sizes of 414 specimens measured during the spring development and the reproduction periods of 1912 and 1913 at Mont Alto, Pa.

This material was taken from vigorous trees. Twigs containing about 200 specimens were cut to secure material for each measurement. To overcome the natural variation in size the 50 largest specimens were removed from the twigs and the largest of these taken each time for measuring. These measurements show the following maxima:

Length, May 16, 1912..... 3.7 mm.
Width, May 30, 1912..... 3.35 mm.
Height, May 24, 1913..... 1.60 mm.

TABLE I.—*Measurements showing growth of 414 females of the terrapin scale during the spring development, Mont Alto, Pa., 1912 and 1913.*

Date.	Number of specimens.	Length.			Width.			Height.		
		Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.
		Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
Feb. 24, 1913	25	1.80	2.375	2.076	1.8	2.275	2.030	0.725	1.10	0.908
Mar. 28, 1913	20	1.726	2.053	1.891	1.633	2.146	1.758	.65	.85	.741
Apr. 8, 1913	20	1.825	2.31	2.114	1.87	2.255	2.060	.73	.975	.854
Apr. 10, 1912	10	1.81	2.2	1.995	1.75	2.2	1.905	.8	1.15	.949
Apr. 11, 1912	3	1.85	1.9	1.88	1.8	1.9	1.833			
Apr. 16, 1912	13	1.6	2.55	1.926	1.5	2.35	1.828			
Apr. 17, 1913	20	1.87	2.53	2.195	1.842	2.365	2.037	.865	1.1	.953
Apr. 19, 1912	10	2.05	2.7	2.372	2.1	2.375	2.302	.825	1.00	.922
Apr. 22, 1912	10	1.7	2.3	2.057	1.6	2.25	1.900			
Apr. 23, 1913	20	2.24	2.98	2.576	1.82	2.613	2.298	.85	1.225	.995
Apr. 26, 1912	10	1.975	2.925	2.314	1.725	2.625	2.200			
Apr. 28, 1913	20	2.613	3.427	2.866	2.24	3.033	2.566	.925	1.275	1.118
Apr. 30, 1913	20	2.706	3.042	2.94	2.473	2.94	2.721	1.00	1.3	1.165
May 6, 1912	6	2.5	2.975	2.666	2.3	2.675	2.458	1.00	1.25	1.437
May 7, 1913	20	2.893	3.22	3.024	2.501	2.893	2.639	1.2	1.50	1.343
May 10, 1913	20	2.8	3.266	3.021	2.52	2.893	2.674	1.05	1.50	1.317
May 16, 1912	10	2.65	3.7	3.127	2.65	3.3	2.94			
May 16, 1913	20	2.94	3.621	3.204	2.52	3.173	2.951	1.225	1.19	1.365
May 23, 1913	20	2.8	3.38	3.046	2.61	3.22	2.851	1.15	1.475	1.333
May 24, 1913	20	2.8	3.36	3.170	2.706	3.266	2.950	1.225	1.60	1.435
May 30, 1912	7	2.5	3.525	3.217	2.7	3.35	3.067	1.07	1.43	1.352
May 31, 1913	20	2.983	3.453	3.177	2.613	2.986	2.844	1.20	1.49	1.319
June 3, 1913	20	2.893	3.593	3.113	2.613	3.08	2.811	1.20	1.55	1.392
June 5, 1912	2	3.05	3.5	3.275	2.5	3.1	2.8	1.325	1.375	1.35
June 7, 1913	20	2.8	3.36	3.102	2.66	3.22	2.885	1.275	1.525	1.383
June 20, 1913	20	2.52	3.173	2.947	2.426	2.986	2.717	1.22	1.525	1.384
June 28, 1912	8	2.6	3.05	2.887	2.7	3.30	2.85	1.075	1.5	1.282
Total	414									

It is doubtful whether individuals ever are large enough to have all the above measurements, since excessive size in one dimension is accompanied by a smaller size in the other dimensions.

The date of greatest average measurements of the same 414 specimens are:

	Mm.
May 30, 1912, length (7 specimens)	3.217
May 30, 1912, width (7 specimens)	3.067
May 6, 1912, height (6 specimens)	1.437

It is evident from these data that the females reach their maximum size between the middle of May and the end of the first week in June.

THE EMBRYO.

The terrapin scale is viviparous. Authors making reference in literature to the eggs of this insect undoubtedly referred to the embryos, which probably were mistaken for eggs. Undeveloped eggs are present in some specimens in the fall before hibernation. Dissections made September 9, 1913, showed a pair of very small racemose ovaries containing a few undeveloped eggs located to the right and left of the alimentary canal, and a small, globular, brown-colored receptaculum seminis attached to the vagina. Dr. Quaintance has observed eggs in hibernating females from Winchester, Va., as early as January 19. The writer has taken rudimentary eggs at various times during the hibernating period. With the renewal of growth in the spring there is a rapid increase in both the number and size of the eggs. The average size of four embryos at birth was as follows: Length, 0.3437 mm.; width, 0.1625 mm.

The data in Table II were taken from the largest embryos obtained at each dissection. Some of these were nearly full size by May 16, although it was not until the first week in June that the eyespots and segments became prominent.

TABLE II.—*Measurements of developing embryos of the terrapin scale, taken by dissection, 1913.*

Date.	Number of specimens.	Average length.	Average diameter.	Locality.
		Mm.	*Mm.*	
May 10	5	0.2986	0.1754	Mont Alto, Pa.
16	4	.3343	.1781	Do.
17	5	.32	.184	Do.
23	5	.344	.173	Do.
27	5	.346	.1625	Midvale, Pa.
June 28[1]	4	.3437	.1625	Mont Alto, Pa.

[1] Measured at birth.

The ovaries remain active and continue to produce eggs as long as nutriment is supplied to them. They are among the last organs of the scale to disintegrate.

Table III gives data from dissections during the spring of 1912 and 1913. These counts show that most of the embryos are formed before the end of May. The greatest number found was 881 on June 4, 1913, and the ovaries of the parent scale were still active. It is evident from this that vigorous females may produce as many as 900 embryos. The oldest embryos are far advanced by June 6, and they are mature by June 15, at which time the eyes, the appendages, and the abdominal segments were clearly seen through the membrane.

TABLE III.—*Rudimentary eggs and embryos from developing females of the terrapin scale, taken at Mont Alto, Pa., during the seasons of 1912 and 1913.*

Date of dissection.	Females dissected on given dates.	Large embryos.	Rudimentary eggs.	Date of dissection.	Females dissected on given dates.	Large embryos.	Rudimentary eggs.
1912.				1912.			
May 27	1	604	Many.	June 15	1	747	Few.
May 28	1	271	Do.	Do	2	611	Many.
Do	2	297	Do.				
May 29	1	349	Do.	1913.			
Do	2	386	Do.	May 16	1	632	Do.
May 30	1	625	Do.	June 4	1	881	Do.
Do	2	463	Do.	June 7	1	734	Do.
Do	3	573	Do.	Do	2	758	Do.
June 5	1	362	Do.	Do	3	689	Do.
Do	2	696	Do.	Do	4	785	Do.
June 6	1	824	Few.	Do	5	663	Do.
June 7	1	684	Do.	Do	6	598	Do.

The data given in Table IV show the number of embryos produced by 13 normal scales during the season of 1912. These data were obtained by isolating the individual scales with tree tanglefoot and taking the daily emergence. When these scales loosened at the end of their reproductive periods they were removed and dissected. The average number of embryos per scale was 406.34. In this experiment approximately 50 per cent of the embryos that formed appeared as migrating larvæ.

TABLE IV.—*Record of progeny and embryos from 13 parent terrapin scales, season of 1912, at Mont Alto, Pa.*

No.	Date of dissection.	Number of embryos, emerging as larvæ.	Embryos taken by dissection.	Total embryos.	Condition of embryos removed by dissection.	Condition of scale when taken for dissection.
	1912.					
1	July 12	142	451	593	One-third dead	Loose and exhausted.
2	15	189	60	249	Mostly dead	Do.
3	3	214	204	418	do	Do.
4	15	245	218	463	do	Nearly exhausted.
5	15	189	192	381	do	Exhausted.
6	10	137	37	174	All dead	Do.
7	15	119	150	269	do	Do.
8	12	303	326	629	One-fourth dead	Black; nearly exhausted.
9	15	220	195	415	Mostly dead	Nearly exhausted.
10	15	168	138	306	All dead	Exhausted.
11	15	187	22	209	do	Do.
12	15	349	193	542	do	Do.
13	15	291	343	634	do	Do.
Total		2,753	2,529	5,282		

It will be noticed from Table IV that most of these scales were removed for dissection upon July 15. These scales were among the most advanced in the orchard. Their exhaustion in the middle of July does not therefore represent the end of reproduction in the orchard, which came much later.

BIRTH OF THE TERRAPIN SCALE, AS OBSERVED AT MONT ALTO, PA., IN 1913.

The following data were obtained by observing 50 scales which gave birth to 3,000 young during the period of 4 days, June 22 to June 26, 1913:

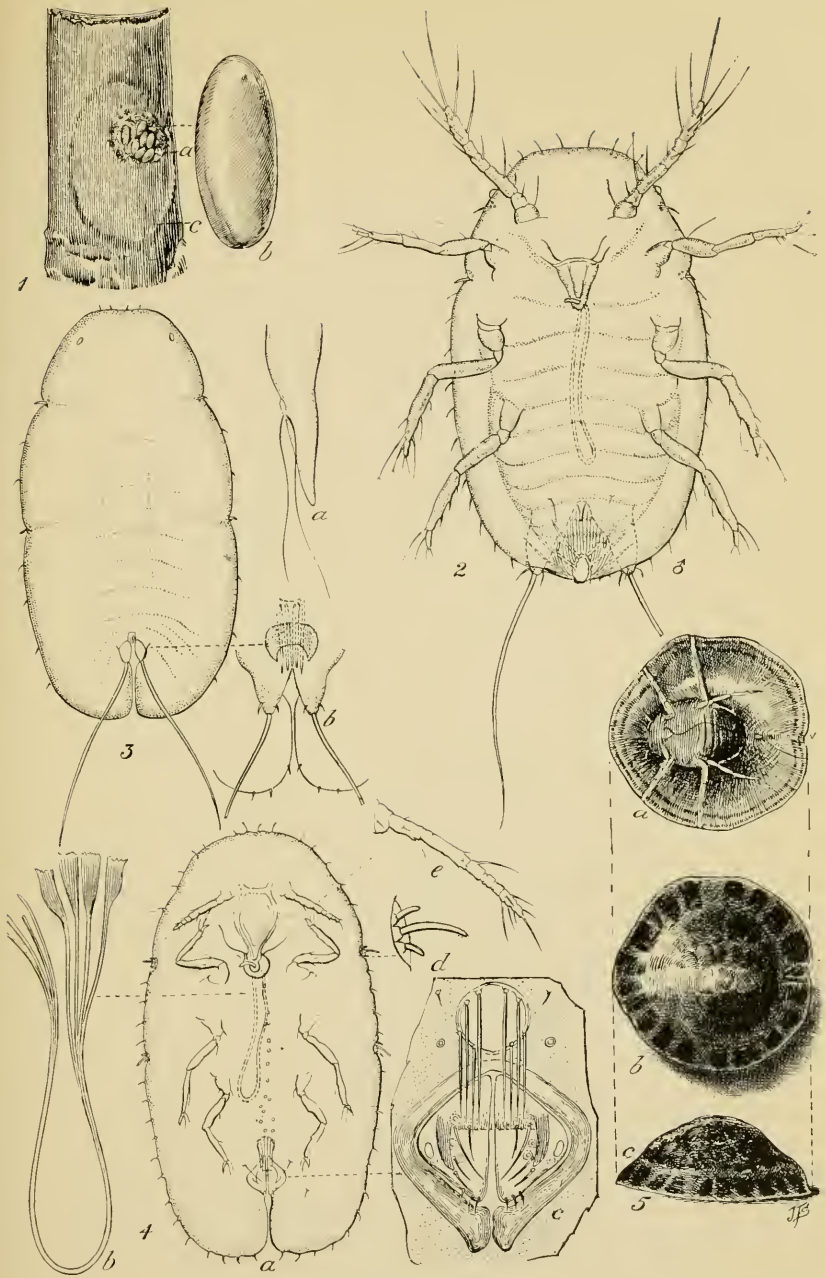
The young are brought forth as embryos, usually inside of a sac or amniotic membrane. The vaginal passage of the mother offers considerable resistance to the passage of the first young of the season, as they are very turgid or swollen, and the amniotic sac is nearly always ruptured, allowing the embryo to escape. This is the only time when they are born free, as later in the season the embryonic sac comes through unbroken. Toward the end of the season the larvæ, after birth, may remain as long as 8 minutes in the embryonic membrane, but the time is seldom more than 4 minutes. The embryos have an average length of 0.36 mm., and a transverse diameter averaging 0.18 mm. (Pl. I, fig. 1, *b*.)

The structure of the larva shows through the amniotic membrane. The antennæ are folded downward and lie parallel along the ventral surface. The proboscis lies between the antennæ and extends along the midventral line for three-fourths of the length of the body. The legs lie alongside the antennæ and extend beyond them to near the posterior end of the body. The major apical setæ and the anal plates are folded forward upon the ventral surface of the body. The eyes show prominently through the membrane. The sides of the body are rolled slightly inward, so as nearly to enfold the ventral appendages. When the embryonic membrane bursts the young appears as a wet, flat larva, which remains motionless for a few minutes, during which the body unfolds and the appendages assume their normal position. The cast membranes of the numerous progeny remain and form a deposit on the floor of the brood chamber. (Pl. I, fig. 1, *a*.) Twenty minutes after birth the larvæ have assumed their characteristic flatness and are moving about in the brood chamber, where they remain usually until the following day, or even longer if unfavorable weather conditions prevail.

Observations of birth are difficult. The displacement necessary for observing this operation loosens the feeding tube and so deprives the parent of the needed nutriment. It is, therefore, impractical to make observations covering an extended interval.

At the beginning of reproduction the time between births may be as short as 2 minutes. As the exhaustion of the parent increases the interval between births becomes longer, until by the thirtieth day birth has practically stopped.

Table V gives birth data for 7 larvæ from well-exhausted parents, under favorable conditions. It shows an average interval between births of 8.5 minutes, and the average time per birth as 2.43 minutes. These birth data can be taken as a good average for the major part



THE TERRAPIN SCALE.

FIG. 1.—Embryos and larvæ as disclosed by removing a female near the end of reproduction: *a*, Embryos in situ; *b*, embryo enlarged; *c*, area covered by the scale. (Enlarged.) FIG. 2.—First-instar male at the leafward migration. (Greatly enlarged.) FIG. 3.—Leaf-attached larva near the end of the first instar: *a*, Lateral view of the caudal extremity; *b*, enlargement of the anal plates. (Greatly enlarged.) FIG. 4.—Female at twigward migration (greatly enlarged): *a*, Anal cleft (greatly enlarged); *b*, enlarged mouth parts; *c*, ventral view of the anal plates; *d*, spiracular spines, more enlarged; *e*, antenna, more enlarged. FIG. 5.—The mature female: *a*, Ventral view; *b*, dorsal view; *c*, lateral view. (Enlarged.) (Original.)

of the reproductive period. The averages are too long, however, for the first 3 or 4 days of reproduction.

TABLE V.—*Birth data of 7 larvæ of the terrapin scale under favorable conditions, Mont Alto, Pa.*

Females.	Number of larvæ.	Temperature at start.	Embryo at orifice.	Birth completed.	Time required.	Interval between births.	Date.	Degree of exhaustion of the female.	Atmospheric conditions.
		° F.	*a. m.*	*a. m.*	*Minutes.*	*Minutes.*	1913.	*Per cent.*	
I	1	75	7.14	7.17	3	.....	June 24	70	Favorable.
I	2	75	7.24	7.28	4	11	...do.....	70	Do.
I	3	75	7.35	7.36	1	8	...do.....	70	Do.
II	1	75	7.16	7.18	2	.....	...do.....	70	Do.
II	2	75	7.24	7.27	3	9	...do.....	70	Do.
II	3	75	7.31	7.33	2	6	...do.....	70	Do.
III	1	75	8.07	8.09	2	.....	...do.....	70	Do.
Average		75	.....	.....	2.43	8.5	.....	.....	

Table VI gives data for 7 larvæ from two well-exhausted parents under rather unfavorable conditions. These data show an average interval between births of 13.87 minutes. They also show that the interval varies widely in the case of different individuals.

TABLE VI.—*Birth data for the terrapin scale under unfavorable conditions, Mont Alto, Pa., 1913.*

Female.	Number of larvæ.	Temperature at start.	Time of birth.	Interval between births.	Date.	Degree of exhaustion.	Weather conditions.
		° F.	*a. m.*	*Minutes.*	1913.	*Per cent.*	
I	1	74	7.37	.....	June 13	70	Unfavorable.
	2	74	7.43	6	...do.....	70	Do.
	3	75	7.50	7	...do.....	70	Do.
	4	76	8.05	15	...do.....	70	Do.
Average for first female		75		9.3			
					1913.		
II	1	76	8.03	.....	June 13	90	Do.
	2	76	8.24	20.6	...do.....	90	Do.
	3	76	8.45	20.75	...do.....	90	Do.
Average for second female		76		20.67			
Average for both females				13.87			

THE YOUNG LARVÆ IN THE BROOD CHAMBER.

In the orchard the larvæ appear in the brood chambers from 1 to 3 days before any of them emerge. During the time of maximum emergence most of the larvæ remain in the brood chamber only until the day following birth. If larvæ are removed from the brood chamber by overturning the scales they migrate at once to the leaves. Even those that have been born but a few hours do this. The maximum time during which they can remain in the brood chamber depends upon their ability to live without food. Experiments indicate that 4 days is the maximum limit of life for unemerged larvæ.

After periods of unfavorable weather lasting from 3 to 5 days dead young are always found in the brood chambers. Unfavorable weather up to 3 days duration does not seem to have an unfavorable effect upon the unemerged larvæ.

EMERGENCE.

Unless weather conditions interfere, the emergence starts upon the second day after the young appear in the brood chambers.

In 1912 a scattered emergence started in the orchard at Mont Alto, Pa., on June 8, with the first young in the brood chambers on June 6. These specimens showed the regular two-day interval between birth and emergence. The regular emergence did not start until a week later.

Emergence from 26 isolated females started June 16, and gave its daily maximum on June 18. Upon June 25, 50 per cent had emerged, and 75 per cent had emerged July 1. Emergence from these scales ceased July 17, after 4,273 had emerged. Twenty-nine specimens in all were isolated at the start of the foregoing experiment. Data from all these are included in Table VII. Specimens numbered 12, 16, and 23 were so manifestly abnormal that they were omitted in calculating the foregoing percentages.

TABLE VII.—*Record of 29 isolated females of the terrapin scale during the emergence period of 1912, at Mont Alto, Pa.*

No.	Total emergence.	Last larva emerged.	Scale loose.	Scale dropped.	Scale taken.	Embryos by dissection.	Number dead embryos.
1	142	July 8	July 12	.....	July 12	451	One-third.
2	121	July 3	July 4	.....	July 5	0	All.
3	189	July 9	.....	.....	July 15	60	Most.
4	214	July 3	.....	.....	July 3	204	Do.
5	245	July 15	.....	.....	July 15	218	Do.
6	189	July 13	July 8	.....	...do.....	192	Do.
7	152	June 26	.....	June 26	.....	.....	
8	137	July 7	July 10	.....	July 10	37	Do.
9	119	July 15	.....	.....	July 15	150	All.
10	143	June 27	.....	June 30	.....	.....	
11	303	July 7	July 12	.....	July 12	326	One-fourth.
12	3	June 21	.....	June 24	.....	.....	
13	146	July 2	.....	July 3	.....	.....	
14	88	July 8	July 11	.....	July 11	8	All.
15	220	July 12	.....	.....	July 15	195	Most.
16	11	June 24	.....	July 7	.....	.....	
17	124	July 15	.....	.....	July 15	97	All.
18	168	...do.....	.....	.....	...do.....	138	Do.
19	71	June 24	.....	June 25	.....	.....	
20	187	July 15	.....	.....	July 15	22	Do.
21	349	July 12	.....	.....	...do.....	193	Do.
22	45	July 15	.....	.....	...do.....	24	Do.
23[1]	1	June 22	.....	June 25	.....	.....	
24	42	July 8	July 8	.....	July 8	145	Do.
25	291	July 6	July 6	.....	July 6	343	Do.
26	144	July 11	.....	July 12	.....	.....	
27	151	July 6	July 11	.....	July 11	359	Most.
28	153	July 15	.....	.....	July 15	148	Do.
29	125	July 8	July 11	.....	July 11	73	Do.
Total	4,273	.....	.....	.....	.....	3,383	

[1] Larva of *Hyperaspis binotata* emerged June 24.

Total embryos, 7,656.

Table VII gives, in summary, the history of the isolated scales used in 1912. It shows the ratio between the number of emerged larvæ and the total number of embryos produced, but it does not show the date of exhaustion of all the scales.

Table VIII gives the detailed emergence of larvæ for 29 isolated females from June 16 to July 15, 1912. At the latter date the scales were nearly all exhausted and 18 of them had dropped. Only 9 were able to produce young at the time of removal. The total number emerging was 4,273. Scale No. 21 gave 349, the highest number of larvæ produced by any of these scales.

TABLE VIII.—*Daily emergence of larvæ from the 29 isolated females of the terrapin scale in Table VII, Mont Alto, Pa., 1912.*

No.	June, 1912.															
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1			1	37		4				3	1	3	1			
2			1			21		14	1	6	10	20	14	17	1	
3						4		7	6	28	8	20	17	26	1	
4				33		33	3	20	25	4	3	9	11	26	24	8
5				22		21	6	16	9	12	7	30	14	16	12	3
6			1	2		8	3	24	18	17	10	12	13	29	3	
7[1]		2	4	37		34	7	2	10	44	6	6				
8		3	4	44		7	4	13	13	5	5	8	6	18	1	
9						8	5	4	8	7	15	20	6	12	1	
10				62		30	12	6	5	4	7	14	3			
11		2	3	110		45	18	15	10	9	12	24	9	24	1	
12						1	2									
13			2	50		46	9	10		16	3	5	3	1		
14				5		9	3		11	20	12	20	5			
15						39	11	16		9	8	14	14		3	
16			1					2	4	4						
17							1		4	4	8	20	13		10	2
18			1	6			7	8	11	11	15	26	10	21	2	
19						15	13	11	5	27						
20			1				4	8	3	9	6	12	6	14	2	
21		2	4	80		48	22	26	19	9	18	20	13	14		
22										1			1			
23[2]								1								
24[3]								4		8	1	2	8			
25[4]			1	32	2	32	11	39	19	21	15	20	13	24	10	2
26							1		1		1	2	7	4	7	
27				14		16	8	15	5	9	7	15	25			
28							14		15	6	8	16	11	19	3	1
29											8	30	6	30	10	5
Total		9	24	534	2	421	164	261	202	296	194	368	229	295	91	21

[1] Dropped June 26.
[2] *Hyperaspis binotata* larva emerged June 24; scale dropped June 25.
[3] Loose and removed for dissection July 8.
[4] Loose and removed for dissection July 6.

TABLE VIII.—*Daily emergency of larvæ from the 29 isolated females of the terrapin scale in Table VII, Mont Alto, Pa., 1912*—Continued.

No.	July, 1912.															Total.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
1	30	14	11	9	.....	19	3	6	.....	.....	.....	.....	.....	.....	.....	142
2	2	10	4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	121
3	33	14	2	2	1	1	.....	11	3	.....	.....	.....	.....	.....	5	189
4	7	1	7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	214
5	21	3	6	10	.....	8	1	11	3	5	.....	.....	.....	.....	8	245
6	23	2	5	3	.....	7	3	4	1	.....	.....	.....	1	.....	.....	189
7[1]	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	152
8	.....	4	.....	.....	.....	.....	2	.....	.....	.....	.....	.....	.....	.....	.....	137
9	9	2	2	3	.....	8	.....	7	.....	1	.....	.....	.....	.....	1	119
10	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	143
11	6	5	.....	2	.....	6	2	.....	.....	.....	.....	.....	.....	.....	.....	303
12	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	3
13	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	146
14	.....	2	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	88
15	43	14	5	10	.....	9	3	9	4	2	4	2	.....	.....	1	220
16	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	11
17	28	6	5	2	.....	3	5	9	.....	1	1	.....	.....	.....	2	124
18	17	7	4	2	.....	7	1	3	2	.....	2	.....	2	.....	3	168
19	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	71
20	36	17	3	9	.....	24	5	7	7	4	3	4	.....	.....	3	187
21	28	11	5	5	1	3	.....	11	6	.....	3	1	.....	.....	.....	349
22	2	3	.....	3	.....	9	11	6	4	.....	2	.....	.....	.....	3	45
23[2]	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1
24[3]	2	.....	.....	.....	.....	.....	.....	17	.....	.....	.....	.....	.....	.....	.....	42
25[4]	13	4	2	4	19	6	.....	.....	.....	.....	.....	.....	.....	.....	.....	292
26	31	12	5	15	.....	13	9	21	8	5	2	.....	.....	.....	.....	144
27	23	3	4	4	.....	3	.....	.....	.....	.....	.....	.....	.....	.....	.....	151
28	7	14	3	2	.....	6	3	7	4	2	3	4	.....	.....	5	153
29	19	6	4	3	.....	2	.....	2	.....	.....	.....	.....	.....	.....	.....	125
Total	380	155	77	88	21	134	48	132	42	20	21	11	3	.....	31	4,273

[1] Dropped June 26.
[2] *Hyperaspis binotata* larva emerged June 24; scale dropped June 25.
[3] Loose and removed for dissection July 8.
[4] Loose and removed for dissection July 6.

The weather was abnormal during the emergence period of 1912. It was very cold, with a daily maximum below 70° F. from June 13 to 15, inclusive. June 19 was rainy and cold, with the daily maximum below 60° F. The daily maximum did not go above 70° until June 22, when it rained. From June 24 to 28, inclusive, the weather was favorable, except for local showers on June 25 and 27. June 29 and 30 were unfavorable, due to a cold rain and no sun. July 5 also was a rainy day. The only favorable weather was from July 6 to 11, inclusive, but it was too late to have an appreciable effect.

The dotted curve on the following emergence graph, figure 2, shows clearly the effect of these weather conditions. The solid line shows the curve as it would probably be in favorable weather.

During 1913 a few larvæ appeared in the brood chambers at Mont Alto, Pa., on June 11. The larvæ were quite abundant in the brood chambers on June 12, and emergence started June 13. Thus the interval between first birth and first emergence was 2 days. The emergence from the isolated scales also started June 13 and the maximum daily emergence was June 18. Fifty per cent and the 75

per cent of emergence came upon June 23 and June 30, respectively. Emergence ceased September 30, after 12,336 larvæ had emerged.

Table IX gives an individual record of the scales observed in 1913, showing the date of exhaustion. It also shows the effect of the

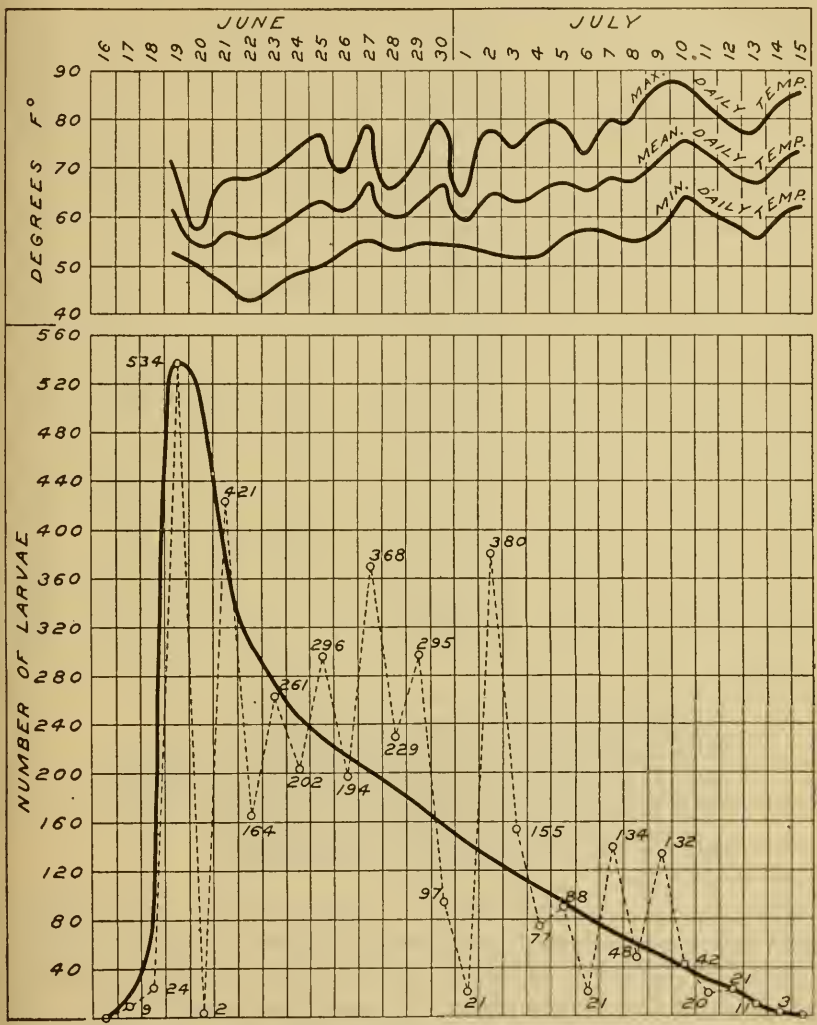


FIG. 2.—Emergence curve for the first 28 days of emergence of the terrapin scale, Mont Alto, Pa., 1912. (Original.)

attack of Hymenoptera and the effect of the predacious beetle *Hyperaspis binotata* Say, but does not show the total number of embryos.

TABLE IX.—*The emergence from 41 isolated females of the terrapin scale during the emergence period of 1913, Mont Alto, Pa.*

No.	Total larvæ.	Last larva emerged.	Parent scale turned black.	Knocked off by accident.	Scale loosened.	Scale dropped.	Scale dead.
1	204	July 14	.....	.....	.....	.....	July 14
2	76	July 1	.....	.....	.....	July 21	July 21
3	494	Aug. 7	.....	Aug. 27	.....	.....	.....
4	206	July 4	.....	.....	July 4	July 4	July 11
5	209	June 29	.....	.....	.....	July 10	June 30
6	233	Aug. 30	Sept. 5	.....	.....	Sept. 30	Sept. 1
7	421	Aug. 26	...do....	.....	.....	Sept. 2	Aug. 28
8	708	Sept. 19	.....	.....	.....	Sept. 30	Sept. 20
9	458	July 20	.....	.....	.....	Aug. 15	July 2
10	796	Aug. 30	.....	Sept. 2	Sept. 1	Sept. 2	.....
11 [1]	245	June 30	.....	.....	.....	July 31	July 1
12	663	Sept. 30	.....	.....	.....	Oct. 11	Oct. 11
13 [2]	221	July 7	.....	.....	.....	Aug. 1	July 8
14	165	June 28	.....	.....	June 22	June 28	June 28
15	53	June 22	.....	June 22	...do....	.....	.....
16 [3]	387	July 21	.....	.....	.....	.....	Aug. 7
17 [4]	389	July 7	.....	.....	.....	Aug. 1	Aug. 1
18 [5]	192	July 2	.....	.....	.....	July 18	July 18
19	174	June 29	.....	.....	.....	July 1	July 1
20 [6 7]	94	June 24	June 15	.....	.....	July 21	June 22
21 [8]	394	July 5	.....	.....	.....	July 18	July 18
22	130	...do....	.....	.....	.....	July 11	July 6
23	240	July 6	.....	.....	.....	July 18	July 7
24	114	June 20	.....	June 22	.....	.....	.....
25	9	June 19	.....	.....	June 21	June 22	June 22
26	389	July 10	.....	.....	.....	July 11	July 11
27	267	June 28	.....	.....	.....	June 29	June 29
28	654	Aug. 18	.....	Aug. 23	.....	.....	.....
29 [9]	472	Aug. 14	.....	.....	.....	.....	Aug. 27
30	309	Aug. 1	.....	.....	.....	Oct. 11	Aug. 2
31 [10]	196	July 3	.....	.....	.....	Aug. 18	Aug. 1
32	42	June 29	.....	.....	.....	July 1	July 1
33	76	July 2	.....	.....	.....	.....	July 3
34	121	June 23	.....	June 23	.....	.....	.....
35	98	June 28	.....	.....	.....	June 28	June 28
36	464	Aug. 7	.....	.....	.....	.....	Aug. 27
37	373	July 14	.....	.....	.....	.....	July 15
38	433	July 26	.....	.....	.....	Aug. 11	Aug. 11
39	391	July 6	.....	.....	.....	Aug. 18	July 17
40	657	Sept. 19	.....	.....	.....	.....	Sept. 20
41	119	July 21	.....	.....	.....	Aug. 23	July 22
Total	12,336						

[1] First instar *Hyperaspis binotata* emerged from this scale July 1.
[2] First instar *Hyperaspis binotata* emerged from this scale July 14.
[3] One hymenopterous parasite (*Coccophagus* sp.) emerged from this scale Aug. 7.
[4] Two hymenopterous parasites (*Coccophagus* sp.) emerged from this scale July 16.
[5] Seven hymenopterous parasites (*Coccophagus* sp.) emerged from this scale July 13.
[6] First instar *Hyperaspis binotata* emerged from this scale July 5.
[7] Three hymenopterous parasites (*Coccophagus* sp.) emerged from this scale July 13.
[8] Second instar *Hyperaspis binotata* emerged from this scale July 18.
[9] First instar *Hyperaspis binotata* emerged from this scale July 18.
[10] First instar *Hyperaspis binotata* emerged from this scale June 30.

The emergence started June 13 with 18 larvæ; the maximum daily emergence occurred upon June 18, when 1,229 larvæ emerged. This was 5 days after emergence had started. The first half of the brood (6,168 larvæ) completed its emergence upon June 23. This was the tenth day of emergence. Seventy-five per cent of the brood (9,250 larvæ) had emerged by June 30. This was upon the seventeenth day of emergence. The daily emergence was not taken for the entire period of 1913, but data for the first 22 days, which cover slightly more than three-fourths of the total emergence, are given in Table X.

Table XI supplements Table X. It carries the emergence through the entire period by weeks. It also gives the date of the end of emergence for each of the parent scales.

TABLE X.—*Daily emergence from the 41 isolated females of the terrapin scale in Table IX, during the first 22 days of emergence, Mont Alto, Pa., 1913.*

No.	June.																		July.				Total.
	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	
1	.....	.....	.....	30	8	15	12	11	18	4	27	5	16	5	12	8	9	4	4	5	.....	.....	193
2	1	.....	.....	5	.....	1	.....	4	2	2	1	14	10	3	11	5	10	.....	1	.....	.....	.....	70
3	.....	1	2	1	20	53	17	30	45	9	71	11	31	8	18	10	8	11	11	8	3	3	371
4	.....	.....	1	.....	10	12	13	40	28	10	15	7	5	5	12	10	13	4	3	11	3	2	204
5	.....	4	2	11	9	20	18	10	56	18	8	3	1	9	20	11	9	.....	.....	.....	.....	.....	209
6	.....	.....	.....	1	7	7	6	14	21	2	28	7	1	3	6	.....	4	6	5	4	7	7	136
7	.....	.....	3	14	27	40	28	39	38	28	2	4	22	3	7	4	9	3	2	15	5	4	297
8	2	.....	8	25	20	36	26	31	37	10	17	8	39	9	30	6	22	18	18	12	2	2	378
9	2	.....	22	22	50	71	24	33	53	45	13	3	25	5	12	11	2	9	8	7	4	2	423
10	.....	.....	3	15	15	27	20	28	43	30	10	16	22	3	13	40	9	48	17	9	3	2	373
11	.....	1	3	2	25	25	10	16	51	20	25	5	35	5	25	1	.....	1	.....	.....	.....	.....	250
12	.....	1	31	16	50	60	18	28	41	15	18	9	30	6	10	12	39	3	2	3	.....	.....	392
13	9	23	18	25	24	40	7	30	4	9	3	6	7	.....	1	7	4	.....	.....	.....	2	.....	219
14	2	4	2	2	20	33	18	37	17	15	6	.....	6	1	1	1	.....	.....	.....	.....	.....	.....	165
15	.....	.....	.....	16	10	12	1	11	2	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	53
16	.....	.....	.....	20	15	29	24	37	60	27	30	4	25	6	30	10	11	3	3	5	5	4	348
17	.....	.....	.....	7	21	50	18	42	68	9	73	11	38	2	12	9	7	9	9	.....	2	.....	387
18	.....	1	12	16	10	22	4	7	15	9	50	3	12	.....	5	23	2	.....	.....	1	.....	.....	192
19	.....	.....	.....	1	8	18	5	2	20	.....	7	2	6	20	47	27	9	.....	.....	.....	.....	.....	172
20	.....	.....	.....	6	9	18	4	7	49	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	94
21	.....	.....	8	.....	.....	5	46	36	57	25	12	30	59	.....	30	29	18	11	11	14	4	3	398
22	.....	.....	14	13	12	13	10	11	10	10	5	5	7	.....	3	.....	.....	.....	.....	8	4	3	128
23	.....	.....	.....	2	26	40	15	23	19	18	6	17	27	4	120	5	4	4	3	8	5	2	348
24	2	6	14	14	7	30	4	27	10	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	114
25	.....	.....	.....	2	1	2	4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	9
26	.....	1	1	12	25	83	26	63	26	6	7	19	25	7	30	10	5	7	7	7	6	2	375
27	.....	1	.....	.....	16	28	31	40	50	2	2	50	26	6	12	3	.....	.....	.....	.....	.....	.....	267
28	.....	.....	.....	12	14	50	38	40	38	16	8	61	7	14	68	20	21	9	9	4	8	4	441
29	.....	.....	.....	.....	9	20	15	22	42	20	14	69	17	6	20	28	5	1	1	.....	3	2	294
30	.....	.....	1	6	4	20	20	32	50	20	20	32	29	7	30	18	3	6	5	2	1	1	307
31	.....	.....	.....	.....	10	27	16	29	28	2	3	30	15	7	25	3	4	.....	.....	.....	1	.....	200
32	.....	.....	.....	.....	.....	4	.....	7	4	.....	1	20	.....	.....	4	1	1	.....	.....	.....	.....	.....	42
33	.....	.....	.....	.....	.....	.....	.....	12	.....	15	20	.....	.....	.....	8	9	10	.....	.....	2	.....	.....	76
34	.....	.....	.....	4	7	30	30	38	.....	6	6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	121
35	.....	.....	.....	.....	.....	4	4	9	20	10	4	13	15	3	7	4	.....	.....	.....	.....	.....	.....	93
36	.....	.....	.....	.....	17	30	20	20	15	7	5	26	16	6	21	25	30	9	11	10	11	5	284
37	.....	.....	.....	10	20	70	38	40	25	75	11	21	11	4	12	4	15	1	2	1	1	.....	361
38	.....	.....	.....	12	20	50	20	52	35	25	15	44	28	10	25	4	10	2	6	4	2	2	366
39	.....	.....	.....	.....	.....	79	30	31	30	21	15	10	20	3	20	13	12	2	3	3	.....	.....	292
40	.....	.....	.....	.....	.....	35	35	36	40	21	20	43	16	2	16	3	3	6	6	6	1	.....	289
41	.....	.....	.....	.....	.....	20	20	16	15	5	2	10	7	4	7	2	2	1	.....	.....	3	1	115
Total	18	43	145	322	546	1,229	695	1,041	1,182	567	580	619	656	176	730	376	310	178	147	151	86	51	9,846

TABLE XI.—*Weekly emergence from the 41 isolated females of the terrapin scale in Table IX, Mont Alto, Pa.*

No.	Total larvæ.	June 13–19.	June 20–26.	June 27–July 3.	July 4–10.	July 11–17.	July 18–24.	July 25–31.	Aug. 1–7.	Aug. 8–14.	Aug. 15–21.	Aug. 22–28.	Aug. 29–Sept. 4.	Sept. 5–11.	Sept. 12–18.	Sept. 19–25.	Sept. 26–Oct. 2.	Emergence ended.
1	204	65	86	42	0	11												July 14
2	76	7	36	27	0	0	6											July 1
3	494	94	205	69	18	25	20	32	31									Aug. 7
4	206	36	110	56	4													July 4
5	209	64	105	40														June 29
6	233	21	76	32	18	26	29	20	6	3	0	1	1					Aug. 30
7	421	106	136	45	37	50	40	3	1	2		1						Aug. 26
8	708	117	151	108	20	40	34	51	21	50	48	13	41	12	1	1		Sept. 19
9	458	191	177	55	22	12	1											July 21
10	796	80	152	109	31	33	67	86	79	50	77	21	11					Aug. 30
11	245	66	157	22														June 30
12	663	170	147	69	13	33	61	56	13	38	26	8	13	8	5		3	Sept. 30
13	221	146	59	14	2													July 7
14	165	81	82	2														June 28
15	53	39	14															June 22
16	387	88	189	67	8	23	12											July 21
17	389	96	243	48	2													July 7
18	192	65	96	31														July 2
19	174	32	59	83														June 29
20	94	37	57															June 24
21	394	53	219	117	5													July 5
22	130	62	48	15	5													Do.
23	240	83	114	39	4													July 6
24	114	77	37															June 20
25	9	9																June 19
26	389	148	153	72	16													July 10
27	267	76	176	15														June 28
28	654	114	184	139	33	16	89	34	27	11	7							Aug. 18
29	472	44	190	58	41	22	54	25	25	13								Aug. 14
30	309	36	190	65	4	1	12	0	1									Aug. 1
31	196	47	114	35														July 3
32	42	4	32	6														June 29
33	76	0	47	29														July 2
34	121	71	50															June 23
35	98	13	74	11														June 28
36	464	67	95	116	15	19	63	62	27									Aug. 7
37	373	138	187	26	18	4												July 14
38	433	102	209	59	13	16	33	1										July 26
39	391	109	221	54	6	0	0	0	1									July 6
40	657	70	178	41	25	39	38	17	45	42	41	46	41	24	9	1		Sept. 19
41	119	40	59	15	1	3	1											July 21
Total	12,336	2,964	4,914	1,831	361	373	560	387	277	209	199	90	107	44	15	2	3	

Table XII gives a summary of these data, with some additional details from Tables VII and IX. It also compares 13 normal females from each isolation.

TABLE XII.—*A summary of the emergence data from Tables VII, VIII, IX, X, and XI.*

No.	Year.	Number of females.	Number of larvæ emerged.	Average number per female.	Emergence started.	Maximum daily emergence.	Emergence, 50 per cent.	Emergence, 75 per cent.	Emergence, 100 per cent.
.....	1912[1]	Total 26	4,258	163.7	June 16	June 18	June 25	July 1	July 15
		Normal 13	2,753	211.8	...do....	...do....	...do....	...do....	Do.
.....	1913	Total 41	12,336	297.95	June 13	...do....	June 23	June 29	Sept. 30
		Normal 13	5,211	400.8	...do....	...do....	June 24	July 10	Do.

[1] All females on twigs were dissected July 15. The isolated females in 1912 had all stopped producing young by July 15.

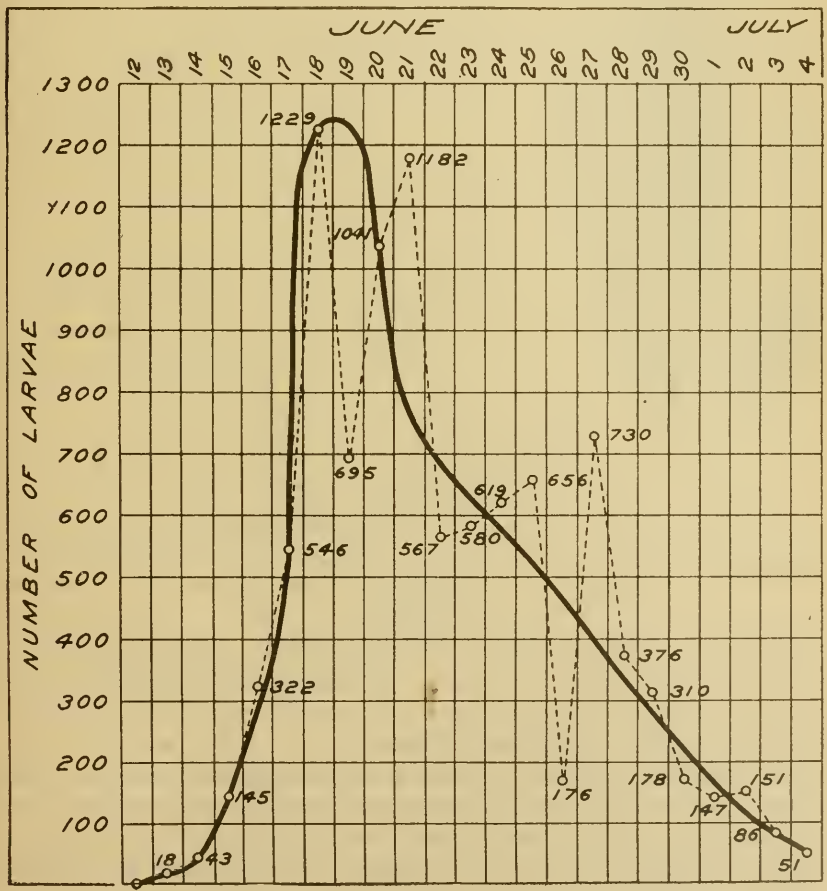


FIG. 3.—Emergence curve for the terrapin scale; first 22 days of emergence, June 13 to July 4, inclusive, Mont Alto, Pa., 1913. (Original.)

The 1912 emergence was shortened by the drying of the twigs to which the females were attached. This was due to the method of isolation. This difficulty was overcome in the 1913 record.

The larvæ of *Hyperaspis binotata* Say were more destructive in 1913 than in 1912, but on the whole both records are very true to the conditions prevailing in the orchard during the respective seasons.

For convenience in comparison and also to show the effect of weather conditions upon this emergence, two graphs, figures 3 and 4,

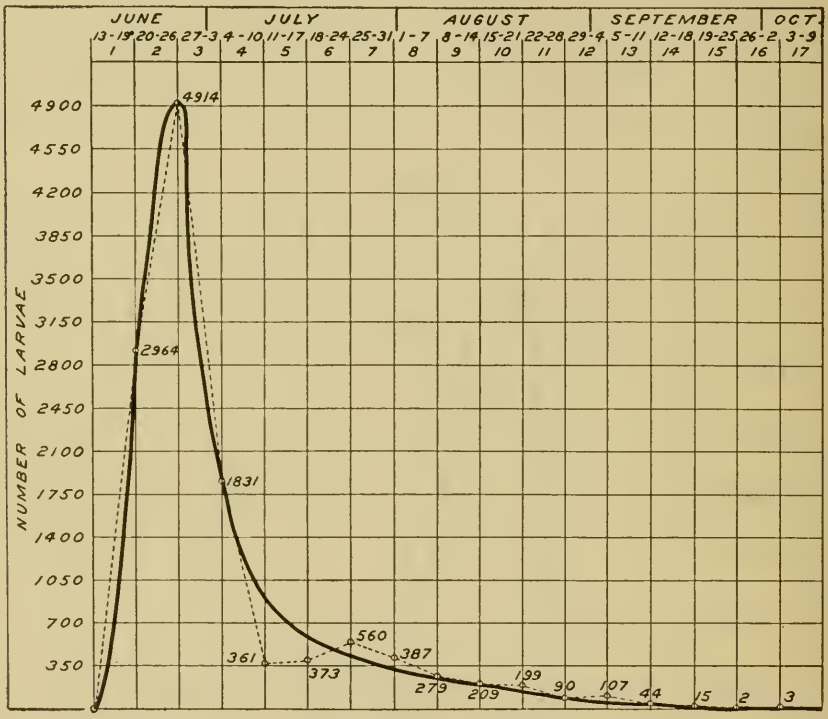


FIG. 4.—Curve of the leafward migration of the terrapin scale for the total emergence period of 1913. (Original.)

are appended. Figure 3 has a solid line added. This represents the weather correction for the curve. In figure 4, where the curve is determined from weekly observations, very little irregularity, due to the daily weather conditions, appears.

The emergence period of 1913 was moderately favorable. The temperature was high and the storms were of short duration. On June 19, 22, and 26 rain checked the emergence, but the larvæ merely remained in the brood chambers over night and emerged on the following day.

The graph of total emergence by weeks during 1913 (fig. 4) shows a very uniform curve. From the graph it appears that the major portion of the young emerged during the first three weeks of the period.

LEAFWARD MIGRATION.

The migration to the leaves begins immediately after emergence. The larvæ start emerging usually about 10 a. m., or even earlier if the temperature is high, and by 3 p. m. the daily migration has nearly ceased. At Mont Alto, Pa., during the noon hours of June 15 to 20, the branches of infested trees were swarming with countless numbers of migrating larvæ. During the leafward migration the larvæ are strongly phototropic and negatively geotropic. The time required for an individual to make this migration and to take its position upon the leaf is remarkably short.

Two hours is about the average time from emergence to the completion of the migration. Many reach the leaves and attach in less than an hour, but others, especially those that have ascended dead branches, may continue to move about for several days if a suitable leaf is not found sooner.

It is very unusual for the larvæ to relocate when they have once taken position upon a leaf, though they do this when the leaf loses its vigor. The larvæ, except in rare and unusual cases, attach to the underside of the leaves, mostly alongside and parallel to the midrib, or the larger veins. (Fig. 5.)

FIG. 5.—Peach leaf with attached larvæ of the terrapin scale. (Original.)

Larvæ usually attach to the first available leaves. The basal leaves upon an infested branch are always more heavily infested than those farther up. A sticky secretion upon the very young leaves repels the young larvæ and prevents them from attaching. The wooly coat of the fruit protects it from larvæ. Larvæ frequently crowd upon the fruit, but in their struggles to free themselves from the fuzz they invariably fall to the ground.

The rate of migration varies with the temperature and the surface upon which the larvæ are placed. Table XIII gives the rate per hour, time, temperature, and the distance traveled by five migrating larvæ of the first instar upon smoked wrapping paper. The average temperature in this experiment was very favorable, being 87° F. The rate per hour was very low, owing to the annoyance caused

the larvæ by the fine soot deposit upon the smoked paper. The distance traveled varied from 97.7 cm. to 175.8 cm. Figure 6 shows a tracing made by four of the above-mentioned larvæ.

TABLE XIII.—*Record of travel of five first-instar terrapin-scale larvæ on smoked paper, Oct. 9, 1912, Mont Alto, Pa.*

No.	Start.	End.	Time.		Distance.	Rate per hour.	Average temperature.
			Hrs.	*Min.*	*Cm.*	*Cm.*	° *F.*
1	9.26 a. m.	2 p. m.	4	34	113.7	26.54	87
2	9.26 a. m.	3.15 p. m.	5	49	175.8	26.596	86
3	11.20 a. m.	2 p. m.	2	40	97.7	36.64	89
4	10.08 a. m.	2 p. m.	3	52	99.6	25.76	87
5	9.26 a. m.	2.50 p. m.	5	24	161.7	29.94	86.7
Average						29.095	87

The larvæ are so small that they leave no trace when moving over the finest soot deposit. The deposit, moreover, retards them. In moving they are constantly exploring the surface with their antennæ, and these soon become coated with soot particles. When this happens the insect halts until the antennæ are cleaned. (For comparison with the rate of progress upon smooth, unsmoked paper, see Table XIV.)

A single larva that emerged at 12.10 p. m traveled, when placed upon plain wrapping paper, 826 cm. during the 3 hours and 20 minutes in which it was under observation. This larva traveled constantly after the first interval, and its speed was about eight times that of larvæ on sooted paper. Figure 7 shows a tracing made of this larva.

TABLE XIV.—*Record of the travel of a newly emerged larva of the terrapin scale on plain wrapping paper, July 10, 1912, Mont Alto, Pa.*

Time of observation.	Temperature.	Total distance.	Interval distance.	Rate per hour.	Average temperature.
	° *F.*	*Cm.*	*Cm.*	*Cm.*	° *F.*
12.10 p. m.	86				
12.25 p. m.	86	35.3	35.3	141.2	86
1 p. m.	86	184.4	149.1	255.6	86
1.15 p. m.	86	239.3	44.9	179.6	86
1.30 p. m.	86	298.3	59	236	86
2.10 p. m.	87.5	473.4	175.1	262.65	86.75
2.30 p. m.	87.5	557.2	83.8	251.4	87.75
3.30 p. m.	88	826	188	282	88
Average				231.356	86.9

In 1912 three experiments were performed to determine the longevity of the leafward migrants when they were unable to reach the leaves. The data from these experiments are recorded in Table XV, and summarized in Tables XVI and XVII. They show that

the migrating larvæ can live from 2 to 3 days. More than 78 per cent of the larvæ died upon the second day, and the mortality of the remainder was about equally divided between the first and third day. It was apparent that the third day was of very little value to the larvæ as they were in a state of collapse.

TABLE XV.—*Longevity of larvæ of the terrapin scale at the leafward migration.*

Experiment No.	Number of larvæ used.	Time of start.	Time of finish.	Surface.	Time of observation.	Number of larvæ dead.
I	3	July 2, 9 a. m.	July 4, 1 p. m.	Dead peach twig	July 2, 9 a. m.	0
					July 3, 9 a. m.	0
					July 4, 9 a. m.	2
					July 4, 1 p. m.	3
II	125	July 7, 12 noon.	July 10, 3.30 p. m.	Exterior surface of test tube over water.	July 7, 12 noon	0
					July 8, 8 a. m.	10
					July 9, 7.30 a. m.	108
					July 9, 12 noon	110
					July 10, 8 a. m.	122
					July 10, 3.30 p. m.	125
III	13	July 4, 8.30 a. m.	July 6, 8.30 a. m.	Inner surface of test tube over water.	July 4, 8.30 a. m.	0
					July 4, 3 p. m.	0
					July 5, 8.30 a. m.	5
					July 5, 4 p. m.	7
					July 5, 9 p. m.	7
					July 6, 8.30 a. m.	13

TABLE XVI.—*Daily mortality of larvæ of the terrapin scale from data in Table XV.*

Day of death.	Experiment I.	Experiment II.	Experiment III.	Dead, by days.	Per cent dead, by days.
First	0	10	5	15	10.63
Second	2	100	8	110	78.01
Third	1	15	0	16	11.34
Total	3	125	13	141	99.98

The summary in Table XVII shows that the average longevity for the three experiments was 2 days 9⅓ hours and the maximum longevity 3 days.

TABLE XVII.—*Maximum longevity of migrating larvæ of the terrapin scale from experiments given in Table XV.*

Experiment.	Number of specimens.	Longest life.
I	3	2 days 4 hours.
II	125	3 days.
III	13	2 days.
Average		2 days 9⅓ hours.

The Leafward Migration as a Factor in the Spread of the Terrapin Scale.

The leafward migration is a strong element in the spread of the scale over the branches of infested trees, but it is not directly effective in spreading it from tree to tree unless the trees are in actual contact.

Indirectly it is one of the strongest factors in the spread of the scale. The young larvæ are not readily displaced by wind, but they sometimes drop purposely from dead twigs, especially when they have reached the tips without finding foliage. Such larvæ may fall upon foliage lower down or drift in air currents to foliage on adjacent trees. Most of them, however, perish on the ground. During windy days particles of bark and loosened leaves are carried by the wind. That wind is a prominent factor in the local spread is indicated by the fact that infestations travel through orchards in the direction of the prevailing wind. Thunderstorms sometimes come so suddenly that the young migrants are washed from the twigs before they have reached the leaves. This seldom happens, because the young do not ordinarily emerge when the humidity is high. The migrants, when displaced by rain, will float for some distance, especially if accompanied by particles of bark or other débris.

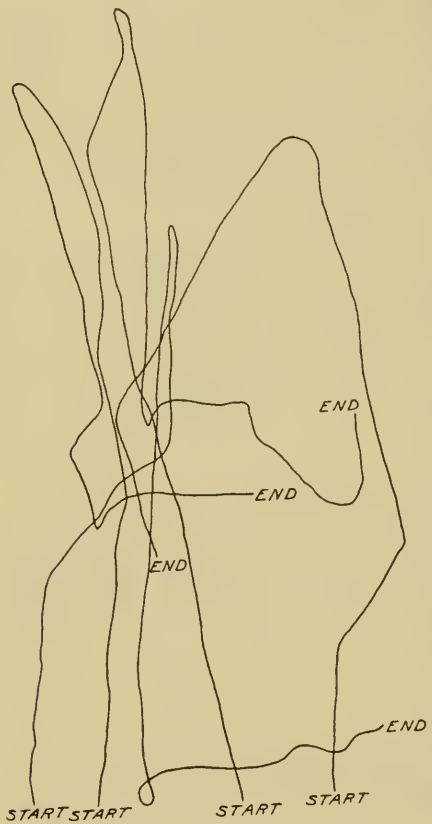


FIG. 6.—Tracing of four young terrapin scales during the leafward migration. Reduced 8 times. Temperature, 87° F. Average rate per hour, 29.095 cm. (Original.)

The spread, except as indicated, requires the aid of some transporting agent. The migrating larvæ cling readily to hairs, to feathers, and to other small objects. While the author has never taken insects with the larvæ attached, he has placed specimens of Brochymena upon branches covered with migrating young, with the result that the larvæ were soon clinging to their legs. Feathers touched lightly to the same branches were clasped by the moving young. A pair of cloth gloves placed for 10 minutes upon a branch had 20 larvæ upon them when removed. This last observation indi-

cates that orchard workers during the migrating period might unwittingly aid in the dispersal of this pest.

It is possible for larvæ of the first instar which have attached themselves to leaves to be transferred to other trees, as the following experiment shows. Thirty larvæ that had loosened themselves from a wilting leaf were placed on the foliage of another tree July 22 at 2 p. m. The first of these was found attached July 23 at 8 a. m., and all of them were attached by July 24 at 8 a. m.

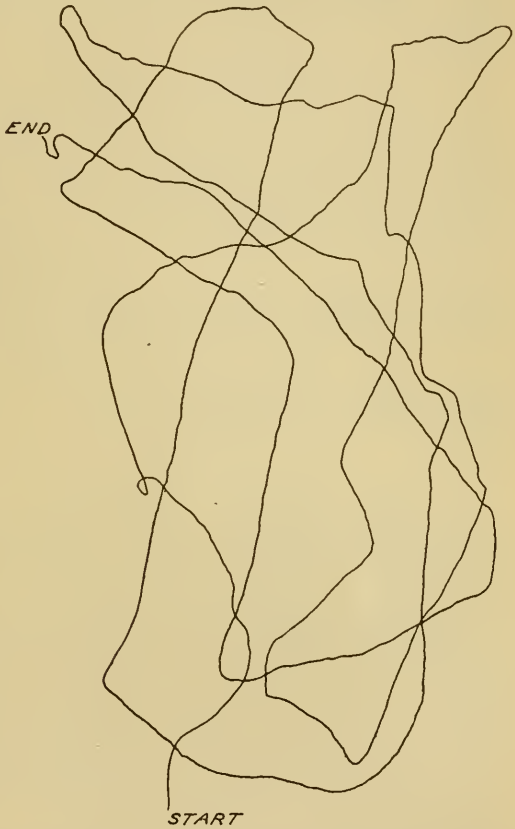


FIG. 7.—Tracings of a young terrapin scale for the first 3 hours and 20 minutes of the leafward migration. Reduced 8 times. Temperature, 86.90° F. (Original.)

Dispersal may occur at this period in at least four ways:

(1) By dropping of larvæ from dead branches, fruit, etc.

(2) By wind transportation.

(3) Through transportation by storm water.

(4) By animate agents (insects, birds, orchard workers, etc.).

MORTALITY DURING MIGRATION.

Practically all of the emerged young make a successful migration. The only exceptions are in cases where the larvæ stray upon dead branches or the fruit and are unable to return and in the case of those destroyed by the occasional attacks of predatory enemies. The mortality at this time is indicated by the small number of larvæ that fail to attach themselves to the leaves. Of the 12,336 larvæ that migrated in 1913 from the isolated scales, all but 15 successfully attached to the underside of leaves. The mortality upon the average orchard tree is slightly higher than is shown in the case of these isolated larvæ.

Size of the Larvæ at Time of Migration.

The size of the larvæ varies. Strong females produce larger young than weak ones. The larvæ are largest at the beginning of reproduction. They gradually become smaller as the season advances. Measurements made in June, 1913, of 10 larvæ give the following results: Length, maximum 0.475 mm., minimum 0.41 mm., average 44 mm.; width, maximum 0.26 mm., minimum 0.20 mm., average 0.23 mm.

Description of the Migrating Larvæ.

The distinguishing characteristics of the leaf migrant are: Average length, 0.43 mm.; average width, 0.23 mm.; color, pale translucent yellow, with reddish brown eye-spots; body very flat and oblong; antennæ with six joints; feeding tube internal and folded midway upon itself. (Pl. I, fig. 2, p. 8.) The anal plates have each a single major apical seta 0.2 mm. in length. The plates have their distal ends just reaching to the tips of the body lobes. These plates are held in a relaxed position, that is, with their adjacent edges forming an acute angle. The terminal anal plates, together with the folded feeding tube, are reliable characters for identifying the leafward migrant.

LEAF-ATTACHED LARVÆ, FIRST INSTAR.

The larvæ emerge, make their migration, and attach to the leaves during the second day after birth, but take no food until after attaching to the leaf. Death by starvation and exhaustion results during the third day after emerging provided an attachment is not made. It is doubtful whether the larvæ can live in the brood chamber more than 4 or 5 days, and at any rate they would be too weak after the fourth day to make an effectual effort to reach the leaves. In 1912 there were several periods in which it was cool and wet for four successive days. After these periods many dead larvæ were found in the brood chambers, some chambers becoming so clogged as to prevent the further escape of young.

The larva, after attaching to the underside of the leaf, retains in the main its earlier characteristics. The proboscis is thrust into the leaf tissues. The anal plates, which during the migration were carried with their adjacent edges diverging, are now held in close contact when in repose. The body lobes, which at attachment were even with the tips of the anal plates, grow steadily backward and inward until they meet behind the anal plates. By this growth the anal plates with their long setæ are made to recede from the posterior edge to a position upon the dorsal surface, as shown in Plate I, figure 3, *a*, *b*, p. 8. A thin, brittle covering of wax appears on the dorsal surface of the larvæ during the latter part of the first instar. All leaf-attached

larvæ that have their anal plates adorned with major apical setæ are in the first instar.

The growth is constant. Both length and width increase in the same ratio. In the first instar the larvæ increase their length and width about two and one-half times, but they do not noticeably increase their height. Tables XVIII and XIX show the measurements for a total of 201 larvæ at various ages during the first instar. The data in Table XVIII are from larvæ that emerged late in the season of 1912. They encountered more than the usual amount of unfavorable weather. The data in Table XIX are from larvæ that emerged in July, 1913, and that had favorable conditions. This table also shows the percentages in the first and second instars at various ages. It required about 25 days for larvæ emerging on August 9, 1912, to reach their full development (0.9 to 1 mm. long) and to molt for the first time, while those emerging July 1, 1913, reached this stage on the sixteenth and seventeenth days.

TABLE XVIII.—*Measurements of 91 first-instar larvæ during the unfavorable season of 1912, Mont Alto, Pa.*

No.	Age.	Number of specimens.	Average length.	Average width.	Emerged—
	Days.		*Mm.*	*Mm.*	
1	0.25	6	0.44	0.23	Aug. 9
2	5	5	.5325	.2044	Do.
3	6	3	.555	.287	Do.
4	7	2	.6046	.276	Do.
5	9	14	.6307	.279	Do.
6	12	6	.8467	.425	Do.
7	15	24	.8968	.439	Do.
8	21	12	.931	.50	Do.
9	22	7	.9348	.499	Do.
10	25	12	.999	.522	Do.
Total		91			

TABLE XIX.—*Measurements of 110 first-instar larvæ during the favorable season of 1913, and the percentages of larvæ on the trees in the first and second instars.*

No.	Age.	Number of specimens.	Average length.	Average width.	Emerged—	Per cent of larvæ in first instar.	Per cent of larvæ in second instar.
	Days.		*Mm.*	*Mm.*			
1	3	22	0.5176	0.2659	July 17	100	
2	5	21	.555	.2873	...do	100	
3	8	15	.7275	.39	July 1	100	
4	15	19	.94725	.5235	...do	100	
5	17	8	.9625	.521875	...do	80	20
6	18	10	.9975	.525	...do	48	52
7	19	5	.97	.52	...do	20	80
8	20	3	.9375	.525	June 26	10.9	89.1
9	21	3	.9916	.5416	July 1	7	93
10	22	3	.925	.525	June 24	10.7	89.3
11	23	1	.975	.55	June 26	3.2	96.8
12	24				July 1		100
Total		110					

The second column in each table gives the age in days. This is calculated from the time the larvæ left the brood chamber. The sixth column gives the date upon which the specimens emerged. There are added to Table XIX two columns of data to show the percentages of larvæ in the first instar and second instar at different ages. An examination of these columns will show that 50 per cent of the larvæ had passed from the first to the second instar upon the

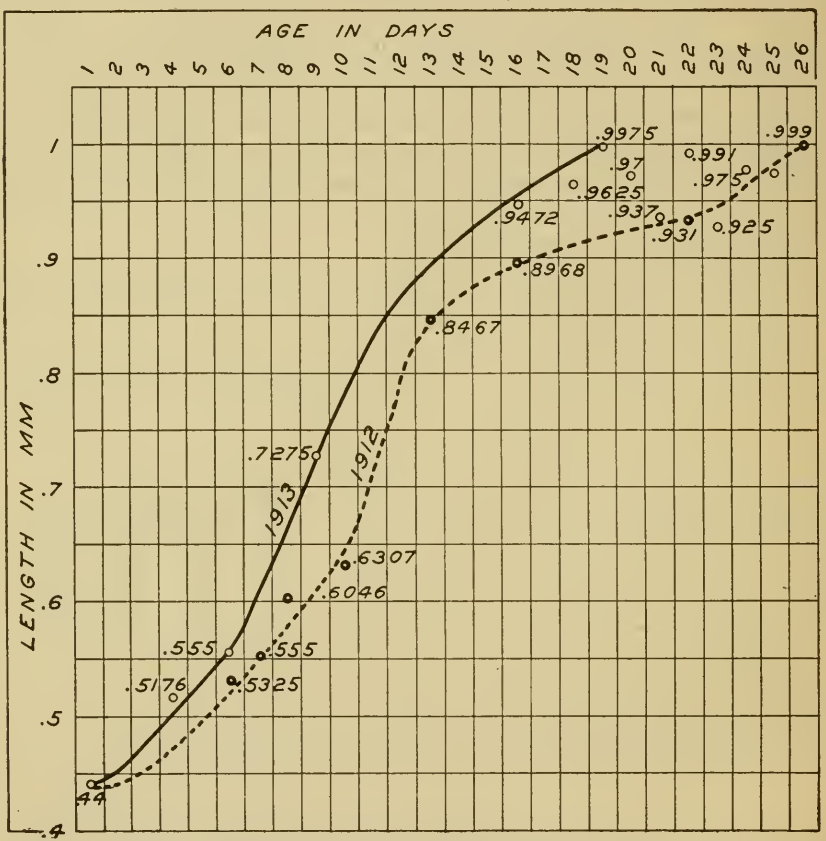


FIG. 8.—Growth curves for the first instar of the terrapin scale. (Original.)

eighteenth day, and that all had left the first instar by the twenty-fourth day. Eighteen days is the normal time spent in the first instar by larvæ during favorable seasons. Figure 8 shows the deflection of the growth curve for larvæ in the first instar which resulted from the late emergence during the unfavorable season of 1912, as compared with the curve for the favorable season of 1913. These curves are derived from the data in Tables XVIII and XIX. The curves are similar, but the broken curve shows clearly the effect of unfavorable weather in 1912 at both the beginning and the end of the instar.

Length of the First Instar.

The earliest molts were upon the sixteenth day and were observed during the very favorable weather of June and July, 1913. Eighteen days is the average length of the first instar at Mont Alto during favorable years, as shown in Table XVIII, columns 7 and 8. This time may be nearly doubled by unfavorable weather. Honeydew is excreted during this instar, but in very small quantities, and is of no economic importance.

Dispersal of First-Instar Larvæ by Leaves.

It is probable that this species is dispersed to some extent by the transportation of larvæ upon wind-borne leaves during storms. An experiment performed July 22, 1913, showed that first-instar larvæ can loosen from slowly drying leaves and that they can move about and reattach to living foliage, so that if infested leaves should lodge in adjacent trees the latter would undoubtedly become infested.

Sexual Dimorphism in the First Instar.

There are no noticeable indications of sex during this instar, except in the anal ring. It is possible in some cases to distinguish the females from the males after the fifteenth day by their increased width. At this time the length of the females is usually less than twice their width, while the length of the males is usually greater than twice their width.

Nearly all specimens are distorted by crowding, or by contact with the veins of the host (fig. 5), so that this variation in the ratio of length to width can not be depended upon for distinguishing the sexes. By dissection, however, they can be distinguished. The anal ring of the male consists of only six setæ, while the anal ring of the female consists of eight.

The First Molt.

There is no change of position at the first molt. The skin splits along the back and is worked downward and backward underneath the body. The last portion to loosen is that about the anal plates. The major apical setæ disappear at this molt; hence the absence of these is positive evidence that the first molt has passed.

The larvæ stop growing one day before molting and become more opaque. The time required to make this molt is from 5 to 30 minutes, depending upon the weather conditions and the vigor of the larvæ. The molt is usually made in the early morning.

Observations made upon 5,000 larvæ approximately one-half of which emerged from June 24 to August 9, 1912, and the others from June 24 to July 1, 1913, show that this molt may take place as early as the sixteenth day and as late as the twenty-sixth day. The aver-

age age for this molt in 1912 was 20 days, but this period is longer than in favorable years. During the favorable season of 1913 a few specimens from the rearing of July 1 made this molt on the sixteenth day, but the largest daily molts were from the eighteenth to the twenty-second day, with the maximum molt upon the eighteenth day. It is, however, very frequently delayed. Table XX gives details of the first molt as shown by three rearings in 1913 and by data obtained in orchards in 1912. It will be noticed that in all cases molting started either upon the sixteenth or seventeenth day and that it terminated in all cases by the twenty-sixth day. The 1913 rearings all had favorable weather and would undoubtedly all have given their maximum daily molts upon the eighteenth day had it not been for a local storm on that date which retarded the natural emergence for the rearings of June 24 and June 26.

TABLE XX.—*Details of the first molt of the terrapin scale from 3 rearings in 1913 and from orchard data of 1912.*

Date larvæ emerged.	Age at starting of first molt.	Per cent molted at various days specified.							Age at maximum daily molt.
		17th.	18th.	19th.	20th.	21st.	22d.	26th.	
	Days.								*Days.*
July 1, 1913...	16	20	52	80	.....	.....	100	.....	18
June 24, 1913.	16	2	.....	.....	.....	40	85	100	22
June 26, 1913.	16	5	20	60	90	91	100	.....	19
Orchard larvæ 1912....	17	.....	(1)	.....	.....	.....	.....	.....	20

[1] Blanks represent days upon which no data were taken. It was impossible to determine, under orchard conditions, the percentage of the total infestation that molted at definite ages.

LEAF-ATTACHED LARVÆ, SECOND INSTAR.

The second instar lasts in favorable weather for 18 days and usually extends from the eighteenth to the thirty-sixth day. In the orchards about Mont Alto specimens can be taken in this instar at almost any time after the middle of July. The instar is at its maximum from July 20 to August 5. This stage of development is characterized by sexual differentiation, which begins very early in the instar. The female larvæ continue to widen and tend to become circular in outline, while the males lengthen and tend to become oval.

The male secretes during this instar the characteristic puparium. This is a waxy scale which forms over the dorsal surface. It is roof-like and is held in place by elastic strands which extend from points upon its edges to the surface of the leaf. (Pl. II, *a*, *e*, p. 52.) It can be recognized as early as the seventh day, but it does not reach its full development until the next to the last day of the instar, at which time growth ceases and the larva shrinks, preparatory to making the second molt.

DEVELOPMENT OF THE FEMALE.

Female Larva, Second Instar.

During the second instar the females increase in length from an average of 1 mm. to an average of 1.6 mm., and in width from an average of 0.525 mm. to 1 mm., but there is very little increase in height.

Table XXI shows the average measurements of 268 females taken at frequent intervals during this instar. These females emerged from June 20 to 26, 1913; that is, during the height of the emergence period.

Table XXI.—*Measurements of 268 female terrapin-scale larvæ of specified ages during the second instar, Mont Alto, Pa., 1913.*

No.	Emerged.	No. of specimens.	Average age at time of entering the second instar.	Age when measured.	Days in second instar.	Average length.	Average width.
	1913.		*Days.*	*Days.*		*Mm.*	*Mm.*
1	June 26	20	19	20	1	1.054	0.558
2	...do....	39	19	21	2	1.076	.590
3	June 24	17	21	22	1	1.063	.55
4	June 26	30	19	23	4	1.114	.638
5	...do....	21	19	24	5	1.257	.676
6	June 24	19	22	26	4	1.431	.775
7	...do....	16	22	27	5	1.380	.776
8	...do....	7	22	30	8	1.471	.892
9	June 21	17	22	30	8	1.395	.713
10	June 20	21	22	31	9	1.504	.835
11	June 26	16	19	32	13	1.506	.937
12	June 24	20	22	33	11	1.587	.978
13	...do....	11	22	34	12	1.575	1.012
14	...do....	14	22	36	14	1.483	.966
Total		268					

The rate of growth is very uniform throughout the second instar, but there is a variation in size among specimens of the same age. This is instanced in lines 8 and 9. Such variations are common and are usually the result of weather conditions or of low vitality in the host. In this instar there is very little growth in height, the average height at the end of the instar being about 0.11 mm. There is no change in color. The excretion of honeydew is moderate and is unimportant. The female has but slight ability to change position and seldom moves from one position to another upon the leaf. Larvæ from withering leaves, when placed upon fresh ones, mostly fail to make a satisfactory attachment.

In an experiment, twigs, the leaves of which were infested with second-instar larvæ, were placed in water. The larvæ soon loosened and migrated to the twigs. The advanced specimens made the second molt prematurely and migrated in the third instar; the young specimens, even those less than half the normal size, migrated also, but without molting. Some of the smaller specimens would undoubtedly have reattached to fresh leaf tissue had there been any on the twigs. The others attached in the normal manner to twigs.

Table XXII shows the time spent in the second instar by larvæ at Mont Alto. The orchard data are derived from the maximum daily emergence and the maximum daily molts. These data show for the season of 1912 a variation in the length of the instar from 16 to 36 days. Most of the specimens in the orchard, from July 20 to August 5, spent 20 days in the instar, while in the rearing of July 22 two-thirds of the larvæ completed the instar in 18 days.

TABLE XXII.—*Data showing the length of the second instar of the terrapin scale from 4 rearings of larvæ at Mont Alto, Pa.*

Year.	Brood.	Emergence.	Beginning of second instar.	End of second instar.	Length of the instar.
					Days.
1912....	Rearing A....	July 22	Twentieth day.....	First specimen, thirty-sixth day	16
				Maximum number, thirty-eighth day...	18
				Last specimen, forty-ninth day.....	29
	Rearing B....	Aug. 9	Twentieth day....	First specimen, thirty-sixth day.....	16
				Maximum number, thirty-eighth day...	18
				Last specimen, fifty-sixth day.....	36
1913....	Rearing A....	June 24	Twenty - second day.	First specimen, thirty-fifth day.....	13
				Maximum number, thirty-ninth day....	17
				Last specimen, fifty-third day.....	31
	Rearing B....	June 26	Nineteenth day...	First specimen, thirty-third day.....	14
				Maximum number, thirty-seventh day..	18
				Last specimen, thirty-ninth day.....	20

In 1913 the maximum daily orchard emergence was two days earlier than in 1912. The first instar required 18 days as against 20 days for the previous year. However, when the age at the end of the second instar is considered, it appears that in both seasons the maximum numbers completed the instar upon the fortieth day.

The larvæ used in Table XXII were placed upon 1-year-old peach trees. For the date of entering the instar is given the day upon which the maximum number entered it, and the date of leaving the instar is given for the first specimen, for the last specimen, and for the maximum daily number.

The table shows that the second instar may last from 13 to 36 days and that the maximum number of specimens remain in it from 17 to 18 days; the greatest number molting upon the eighteenth day.

SECOND MOLT OF THE FEMALE.

The second molt of the female coincides with that of the male and is little more than the casting of the skin in response to growth. There is no change in the structure of the appendages or of the mouth parts.

In 1912 the second molt for a rearing of 213 females that emerged July 22 extended over a period of 10 days. The maximum daily molt was upon the thirty-eighth day after emergence, and 50 per cent had molted by the fortieth day. A rearing of 100 females that emerged upon August 9, 1912, made its maximum molt upon the thirty-eighth day after emergence. One-half of the rearing molted upon that day.

In the orchards at Mont Alto, Pa., in 1912, the maximum molt was upon the fortieth day. In all the rearings there was a very short interval between the first molt and the maximum daily molt. This interval varied from 2 to 5 days, with 3 days as the normal time.

In 1913 observations were made upon two rearings, one of which emerged June 24. This rearing of 174 females made its maximum daily molt upon the thirty-ninth day. Reference to Table XXII will show that the first molt for this rearing was made upon the twenty-second day. It was slightly delayed by a storm, but the larvæ reached the maximum of the second molt on the thirty-ninth day; that is, 1 day ahead of the average time for the orchard larvæ.

TABLE XXIII.—*Age of the terrapin scale at the second molt as determined from the maximum daily molt.*

Year.	Material.	Number of specimens.	Age at the maximum daily molt.	Weather conditions.
			Days.	
1912....	Brood of July 22	213	38	Unfavorable.
	Brood of Aug. 9	100	38	Do.
	Brood of orchard [1]	1,765	37	Do.
	Average for the year		37.1	
1913....	Brood of June 24	174	39	Favorable.
	Brood of June 26	69	37	Do.
	Brood of orchard [1]	190	36	Do.
	Average for the year		37.3	

[1] These data refer to larvæ reared upon isolated twigs at Mont Alto, Pa., and not to the entire orchard brood.

The foregoing data show that the averages for the two years differ by only two-tenths of a day. Some of the individuals, however, departed 4 or 5 days from this average, while in 1912 some specimens made the molt as late as the forty-second day and in 1913 some made it as early as the thirty-second day.

LEAF PHASE OF THE THIRD INSTAR.

After molting to the third instar the females remain motionless on the underside of the leaf for a period of 1 day while they secrete a very thin dorsal scale which protects them during migration to the twigs.

The individuals vary in size in the same season, and there is a slight variation in the average size from year to year. The measurements from 11 specimens showed a minimum length of 1.387 mm. and a minimum width of 0.862 mm.; a maximum length of 1.65 mm. and a maximum width of 1.074 mm.; an average length of 1.545 mm. and an average width of 0.995 mm. The average length in 1912 was 1.465 mm. and the average width 0.974 mm. In 1913 the average length was 1.64 mm. and the average width 1.02 mm., showing an increase in size for the latter year of 0.175 mm. in length and 0.046 mm. in width.

Migration to the Twigs.

The twigward migration of the females starts about the 1st of August and reaches its maximum before the middle of the month, after which it continues in a small way until the leaves fall. In the vicinity of Mont Alto, Pa., from 80 to 90 per cent migrate between August 8 and August 20. (Pl. I, fig. 4.)

Table XXIV gives data from observations made upon 1,494 migrating females during 1912 at Mont Alto, Pa. The observations in Part I were made upon larvæ that settled naturally upon orchard trees. The material considered was isolated with tree tanglefoot August 1 and the females as they migrated were removed and counted at two-day intervals. The age at which these particular larvæ migrated is not definitely known, but was about 40 days. The rearing of July 22 (Part II) migrated from the thirty-ninth to the fiftieth day after emergence, and made its maximum daily migration August 30, which was the thirty-ninth day. The rearing of August 9 (Part III) migrated from the thirty-first to the fifty-seventh days and made its maximum daily migration upon September 15, which was the thirty-seventh day. It is evident from a comparison with figure 11 that the maximum in Part III was retarded. A cold wave, which started September 7, retarded the maximum daily migration, causing it to be nearly a week after the start.

Table XXIV.—*The time of the twigward migration of 1,483 female larvæ of the terrapin scale, Mont Alto, Pa., 1912.*

Part.	Material observed.	Number of larvæ.	Twigward migration.		Part.	Material observed.	Number of larvæ.	Twigward migration.	
			Date.	Number migrated.				Date.	Number migrated.
I.....	Orchard larvæ, Mont Alto, Pa.	976	Aug. 12	0	III...	Rearing of August 9.	294	Sept. 8	0
			14	283				9	2
			16	176				10	5
			18	202				11	13
			20	120				12	24
			22	65				13	23
			24	33				14	18
			26	32				15	65
			28	24				16	20
			30	13				17	18
			Sept. 1	10				18	20
			3	12				19	11
			5	6				20	24
II....	Rearing of July 22.	213	Aug. 30	61				21	5
			31	19				22	10
			Sept. 1	6				23	5
			2	50				24	8
			3	20				25	9
			4	17				26	3
			5	14				27	3
			6	10				28	1
			7	7				29	0
			8	4				30	0
			9	3				Oct. 1	1
			10	2				2	0
			11	0				3	0
			12	0				4	0
								5	6
						Total.....	.....	.....	1,483

The orchard larvæ considered in Table XXIV, Part I, had very favorable weather during their twigward migration. The relation of this migration to the prevailing temperature is shown graphically in figure 9. The migration curve shows the shortness of the interval between the start of migration and its maximum.

The migration started on August 13 and was 50 per cent complete upon August 17. Thus, one-half of the migration was made during

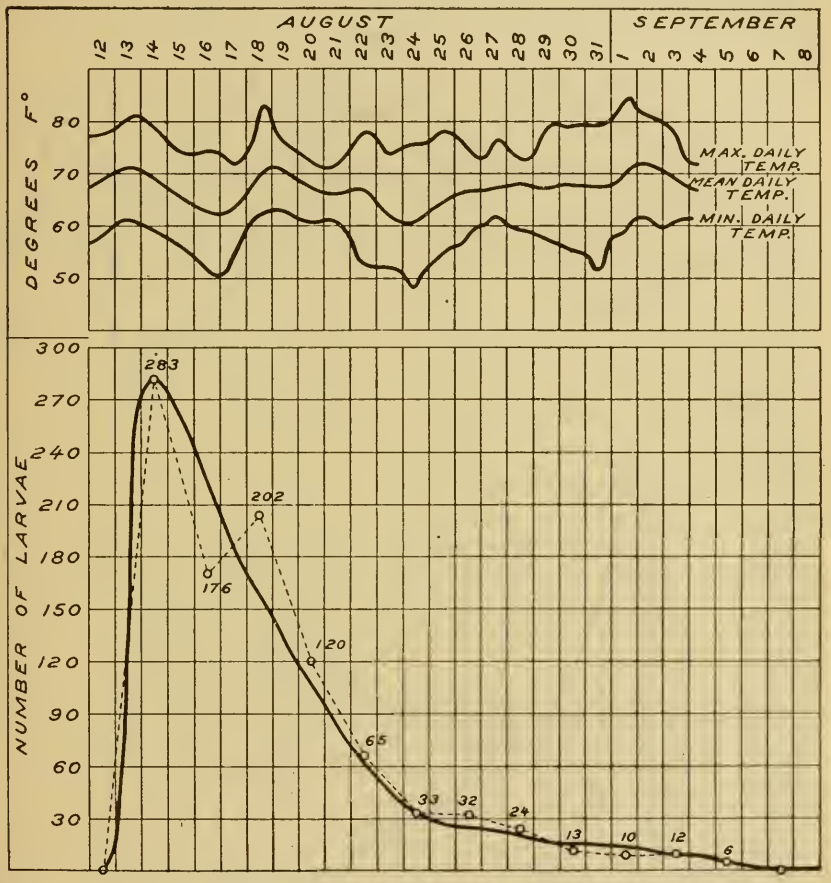


FIG. 9.—Curve of the twigward migration of the terrapin scale for the orchard larvæ of 1912. (Original.)

the first four days of the period. This curve is typical for the migration in favorable seasons.

The larvæ considered in Table XXIV, Part II, encountered very unfavorable weather during the period of migration. Cold interfered at the beginning, and rain continued throughout most of the period. The effects of these conditions are shown graphically in figure 10. The solid curve represents a normal migration, the dotted curve the migration under prevailing conditions. This graph

also includes the data for rainy and clear days. August 28 was clear and favorable and the following day was rainy. August 30 was clear, and migration started. August 31 to September 2 was

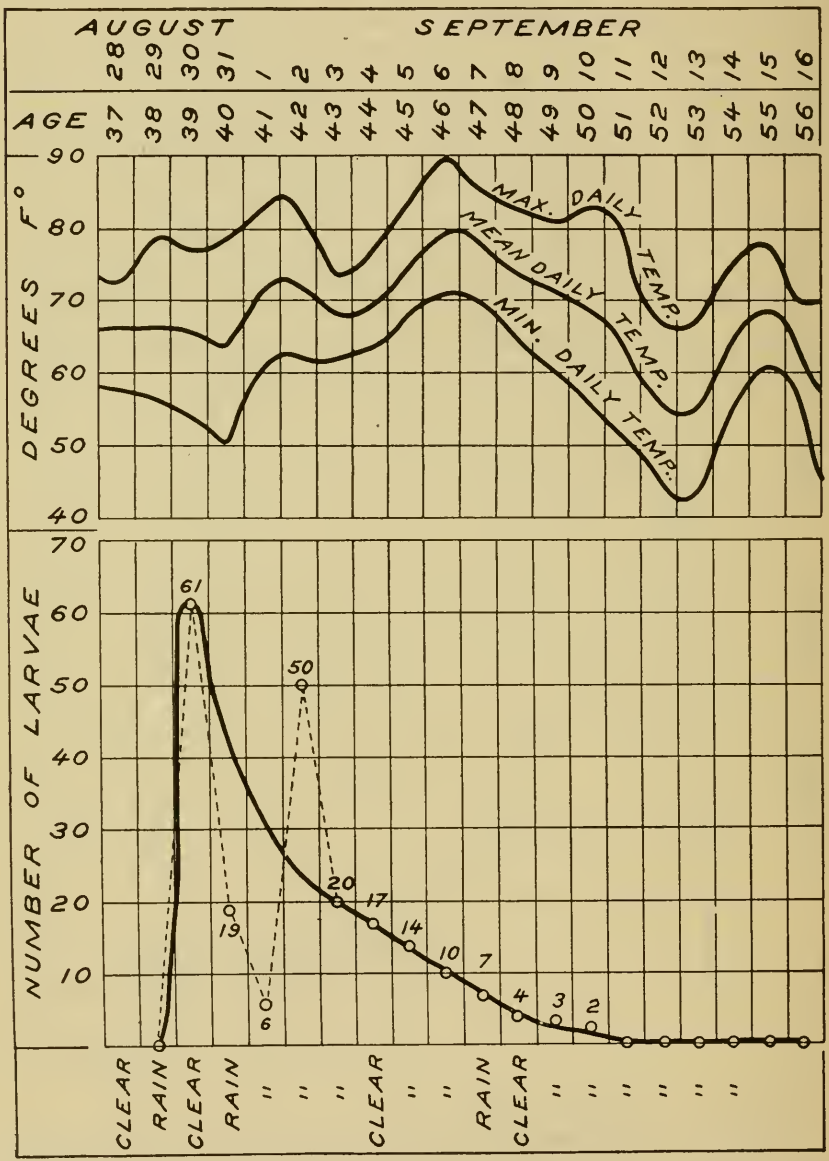


FIG. 10.—Curve of the twigward migration of the terrapin scale for a rearing that emerged July 22, 1912. (Original.)

rainy, but on the last of these days it was clear and hot in the afternoon, thus permitting a heavy migration. The remainder of the period was clear, except for slight rains upon September 3 and 7.

During the migration of the rearing of July 22 the maximum daily temperature rose gradually from 73° F. on August 28 to 85° F. upon September 1, after which it fell to 74° F. upon September 3, and then rose abruptly to 90° F. upon September 6. It then dropped to 67° F. upon September 12. The average daily temperature remained nearly constant at 66° F. from August 28 to August 31,

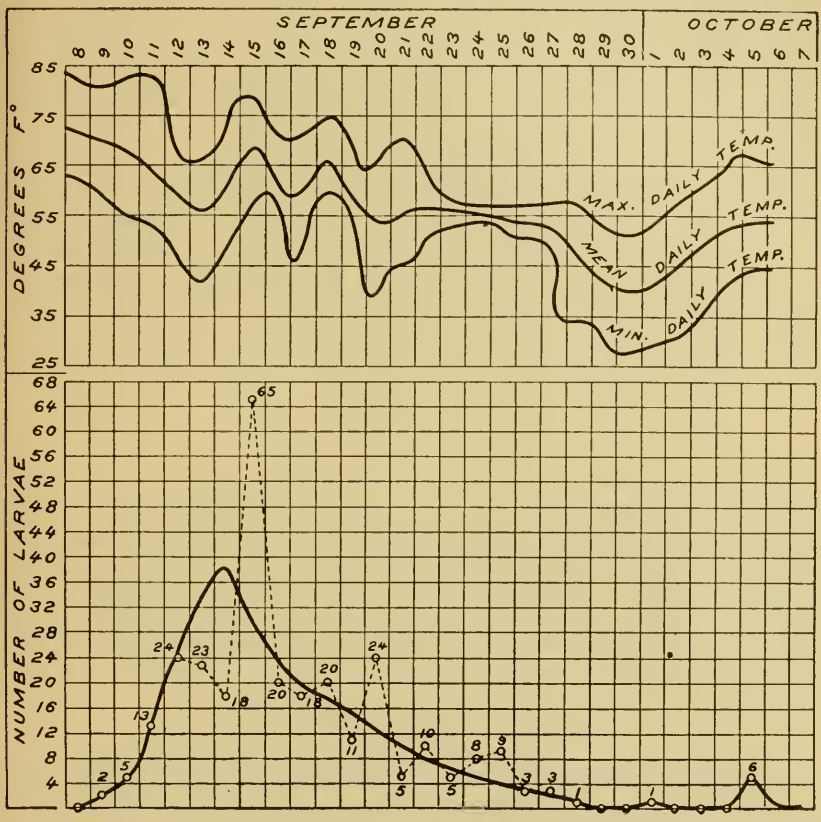


FIG. 11.—Curve of the twigward migration of the terrapin scale for a rearing that emerged August 9, 1912. (Original.)

when it rose abruptly to 73° F. upon September 1. During September 2 and 3 it made a gradual drop to 68° F., and then rose in a gradual way to 80° F. upon September 6. This was followed by a gradual drop to 54° F. upon September 12. This rearing gave its maximum daily migration when 39 days old and its 50 per cent of migration four days later.

The larvæ considered in Part III of Table XXIV were a late rearing. They had favorable weather to near the end of the second instar, but very unfavorable weather during the twigward migration. The

relation of the temperature to the migration of this rearing is shown in figure 11.

This migration extended from September 8 to October 5, 1912, under unfavorable temperature conditions. There was a drop in the average daily temperature from 71° F. on the first day of migration to 56° F. on the sixth day (September 13). This was followed by a favorable day, when the average temperature rose to 69° F., after which it dropped gradually to 40° F. at the end of September. There was a rainstorm of three days' duration, September 23, 24, and 25, but it came too late to modify the rate of migration to any extent. Under these conditions 95 per cent of the rearing had migrated by the end of the tenth day of migration, or by the fortieth day after emerging. The maximum daily migration was made by this rearing upon the seventh day after the start of migration; that is, upon the thirty-seventh day after emerging. A comparison of the curves, figures 9 to 11, shows that the curve for optimum conditions (fig. 9) tends to have a perpendicular ascending slope and a very steep receding slope, and that unfavorable conditions tend to flatten the curve and to cause serrations in the slopes.

TIME REQUIRED FOR MIGRATION.

The migration is made during the hottest part of the day. Usually very few migrating specimens can be taken until after 12.30 p. m., because of the low morning temperatures. The larvæ start upon this migration when the temperature reaches 70° F. By 1.30 p. m. larvæ are usually moving in great numbers upon the twigs. By 3 p. m. nearly all migrants have selected their locations and permanently established themselves.

LONGEVITY OF MIGRANTS.

In case the twigward migrants are prevented from attaching, they can live for 2 days, and a small percentage even for 3 days before dying.

The following experiment was made to determine the longevity of a twigward migrant when prevented from attaching. A quantity of material was kept under observation from August 30, 1913, until one of the larvæ was observed to start upon its migration. This specimen was then placed upon wrapping paper for observation. The details of these observations are shown in Table XXV.

TABLE XXV.—*Rate per hour and distance traveled by a migrating larva of the terrapin scale upon wrapping paper during the total time of the twigward migration, Mont Alto, Pa., 1912.*

LARVA NO. 1.

	Observed—	Interval.	Distance.	Rate per hour.	Temperature.
		Min.	*Cm.*	*Cm.*	° *F.*
Aug. 30	2.45 p. m.				70
	3.15 p. m.	30	30.6	61.2	84
	3.30 p. m.	15	27.8	111.2	88
	4 p. m.	30	62	124	90
	4.30 p. m.	30	61.5	123	80
	4.45 p. m.	15	16.2	64.8	78
	5 p. m.	15	15.4	61.6	77
	5.15 p. m.	15	9.1	36.4	76
	6 p. m.	45	9.3	12.4	72
	Total	3 h. 15 m.	231.9		
Aug. 31	2.30 p. m.				70
	3.15 p. m.	45	8	10.6	86
	3.30 p. m.	15	1.7	6.8	88
	4.15 p. m.	45	17.3	23.06	82
	4.30 p. m.	15	3.2	12.8	78
	6 p. m.	90	8.6	5.7	75
	6.30 p. m.	30	2.7	5.4	72
	Total	4 h.	41.5		
Sept. 1	8.45 a. m.				70
	9.20 a. m.	35	3.6	6.17	72
	9.30 a. m.	10	.4	2.4	80
	10 a. m.	30	7.9	15.8	86
	11 a. m.	60	25.1	25.1	88
	12 noon	60	12.1	12.1	84
	Total	3 h. 15 m.	49.1		

Migration, first day: Migration started at 2.45 p. m., and continued until 6 p. m., when it stopped. The larva remained motionless all night. During the time of migration, which was 3¼ hours, the larva traveled 231.9 cm. It traveled at a rate of 124 cm. per hour from 3.30 p. m. to 4 p. m., with a rate of 123 cm. per hour from 4 to 4.30 p. m. The rate then fell off rapidly after 4.30, being 36.4 cm. per hour for the interval from 5 to 5.15 p. m., and only 12. 4 cm. per hour for the interval from 5.15 p. m. to 6 p. m. The temperature during this migration rose gradually from 70° F. at 2.45 p. m. to 90° F. at 4 p. m., and then fell to 72° F. at 6 p. m. The highest rate of travel therefore coincided closely with the time of highest temperature.

Migration, second day: The larva remained motionless from 6 p. m., August 30, until 2.30 p. m., August 31, when it again started to migrate and continued until 6.30 p. m., an interval of 4 hours, during which it showed signs of exhaustion and traveled only 41.5 cm. The rate per hour gradually increased from the start until it reached a maximum of 23.06 cm. per hour for the period 3.30 p. m. to 4.15 p. m., after which it dropped to 12.8 cm. per hour during the next interval and then to 5.4 cm. per hour for the last interval. The temperature during this second day's migration was slightly lower than on the previous day. The temperature at the resumption of migration, 2.30 p. m., was 70° F., from which it rose rapidly to a maximum of 88° F. at 3.30 p. m., and then dropped gradually to 72° F. at 6.30 p. m.

Migration, third day: The third day was very warm. The larva had remained motionless from 6.30 p. m., August 31, to 8.45 a. m. of the following day, at which time it resumed migration and continued until 12 noon, when it died, after traveling for 3¼ hours, during which time it advanced 49.1 cm. The rate of travel, which was very low, reached its maximum of 25.1 cm. per hour in the interval ending at 11 a. m., after which it dropped to 12.1 cm. per hour for the interval between 11 a. m. and 12 noon. The temperature during the third day was very favorable. It reached 70° F.

at 8.45 a. m., at which time the larva resumed its migration. At 9.30 a. m. the temperature was 80° F., at 10 a. m. 86° F., and at 11 a. m. 88° F., from which hour it dropped to 84° F. at noon, when the experiment was terminated by the death of the larva.

Ordinarily larvæ start migrating when the temperature reaches 70° F., and the rate of travel increases in nearly the same ratio as the increase in temperature above 70° F. Larvæ, if unattached, become motionless when the temperature falls below 72° F. The female

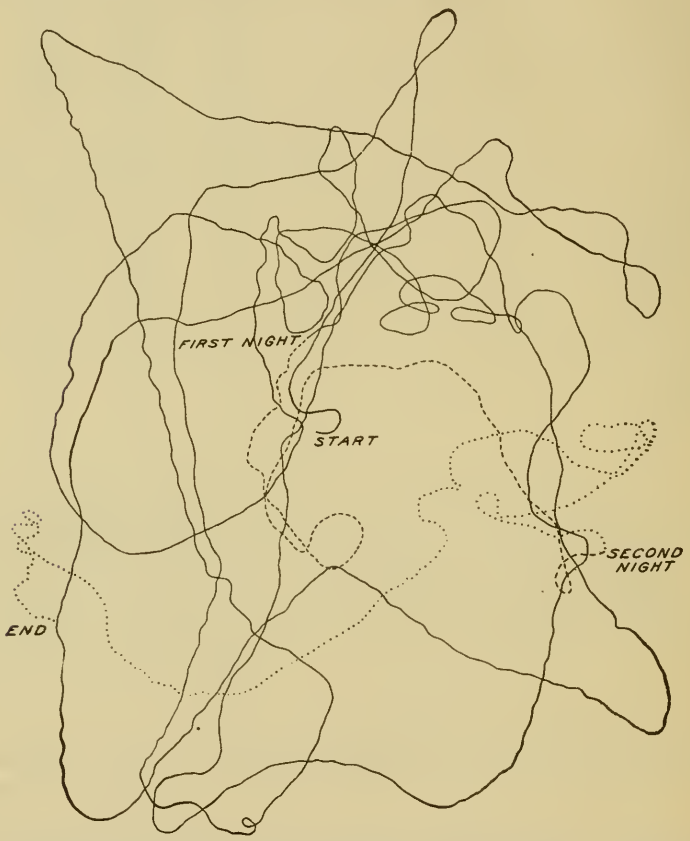


FIG. 12.—Tracing of the total twigward migration of a female larva of the terrapin scale. Reduced 8 times. Total distance traveled, 322.5 cm. (Original.)

under observation started migration August 30 at 2.40 p. m., and died September 1 at 12 noon, having lived 2 hours and 40 minutes less than 3 days, and having traveled over smooth paper a distance of 322.5 cm. (10½ feet). (Fig. 12.) This was undoubtedly farther than the average specimen is able to travel upon its host plant. *There is therefore very little chance of the larvæ crawling to adjacent trees unless the limbs are in contact.*

A second female larva (Table XXV), captured August 26, during the first day of migration, was placed upon wrapping paper at 2.25

p. m. This larva traveled 192 cm. in 2 hours and 35 minutes at an average rate per hour of 74.84 cm. (Fig. 13.)

FIG. 13.—Tracing of a female larva of the terrapin scale for 2 hours and 35 minutes during the first day of the twigward migration. Distance traveled, 192 cm. (Original.)

TABLE XXVI.—*Rate per hour and distance traveled by two migrating larvæ of the terrapin scale on wrapping paper.*

Larva number.	Observed—	Interval.	Distance.	Rate per hour.
		Min.	*Cm.*	*Cm.*
2	2.25 p. m.			
	2.47 p. m.	22	58	158.88
	3.40 p. m.	53	57	64.23
	4 p. m.	20	31.6	94.8
	4.45 p. m.	25.7	25.7	34.26
	5 p. m.	15	21	84.00
Total		2 hrs. 35 m.	192	74.84
3	11 a. m.			
	11.30 a. m.	30	53.5	101.5
	12 noon.	30	45	90.
	12.30 p. m.	30	48.1	96.2
	1 p. m.	30	37.5	75
Total		2 hrs.	181.1	92.05

A third larva, Table XXVI, taken September 1, 1912, at 11 a. m., while in the first day of migration, gave a maximum rate per hour of 101 cm., at 88° F., and an average rate for 2 hours of 92.05 cm. (Fig. 14.)

The rate of migration depends both upon the temperature above 70° F. and upon the length of time that has elapsed since the migration started.

It is very exceptional for specimens to require more than one day for the twigward migration. More than 90 per cent of the females

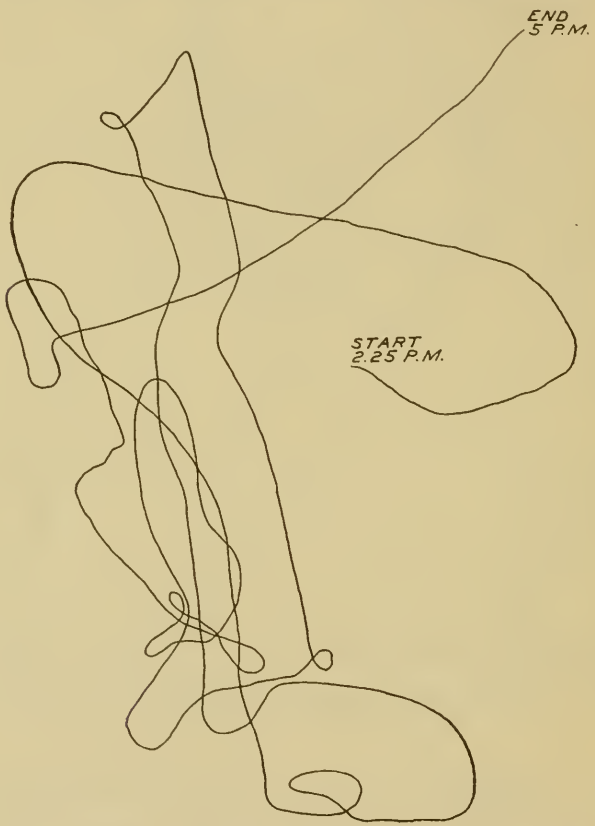


FIG. 14.—Tracing of a female larva of the terrapin scale for the first two hours of the twigward migration. Reduced 8 times. Total distance, 184.1 cm. (Original.)

complete this migration during the first 4 hours. Females may occasionally shift to a more favorable position during the second and third days' sojourn upon the twigs, but after this they remain in one place.

During the day preceding the twigward migration the female larvæ secrete a thin scale which covers the dorsal surface and gives rigidity to the flat, leaf-shaped body. The larvæ in migrating pass down the petiole and move along the twigs toward the region of greatest illu-

mination. They finally reach the tips of the twigs, where they locate by preference upon the basal part of the young growth. Many, however, locate upon 1-year-old wood, and a few upon the 2-year-old wood. Other parts of the tree are very seldom infested. The larvæ settle by preference upon the underside of horizontal limbs and upon the unshaded side of vertical branches. There is a tendency for them to group themselves in rows upon the illuminated sides of the twigs. The individual scales within these rows are not necessarily in alignment, either with their neighbors or with the axis of the twig. This linear arrangement results solely from their instinctive desire to locate in the area of greatest illumination, which, from the nature of the twigs upon which they locate, is always many times longer than wide. During migration the mortality is very low.

The females are very flat and have the pale yellow color of the preceding stages. This color appears rather lighter than in the second instar, due, no doubt, to the effect of the nearly transparent dorsal scale. The only colored portions at this time are the brown eyespots and the chitinized anal plates.

Specimens measured in 1912 and in 1913 were from 1.23 to 1.57 mm. in length and from 0.65 to 1.12 mm. in width, the average height being about 0.1 mm. The average size for both seasons was, length 1.47 mm., width 0.98 mm.

The Female Upon the Twig: Development During the First 20 Days.

After attaching to the twigs the young females begin a period of rapid growth. A small red blotch, which appears over the oral region either during the migration or immediately after it, begins at once to enlarge and to form itself into a narrow band of a reddish-brown color which extends backward along the middorsal line until by the sixth day it reaches the anal plates. (Fig. 15, *a*.) Meanwhile the dorsum changes from a flat to a mildly arched surface and the larva increases from about 1.54 to 1.65 mm. in length and in width from 1.03 to 1.29 mm. When the dorsal band reaches the anal plates it forks. Each fork when developed equals the original band in width and is slightly longer than wide. These forks start about the sixth day and are about one-half completed by the eighth day. From the sixth to the tenth day there is a very decided arching of the dorsum. Growth is greatest just in front of the anal plates, and the elongation of the dorsum at this place first constricts and then breaks the dorsal band, leaving a short piece of it attached to the forked portion that is forming about the anal plates. (Fig. 15, *b*.) Later the anterior piece is displaced forward and shrinks until it becomes inconspicuous just above the oral region. About the eleventh day after migrating, the forks of the dorsal band are completed. This band is a secondary sexual character, which, after copulation, fades and blends with the

reddish-brown ground color. The rent between the two parts remains unpigmented and shows in mature specimens as the characteristic dorsal stripe. (Pl. I, fig. 5, *b*, p. 8, and text fig. 15, *d*.)

Up to and including the eighth day the general aspect is strictly larval, except for the slight arching of the dorsum and for the dorsal

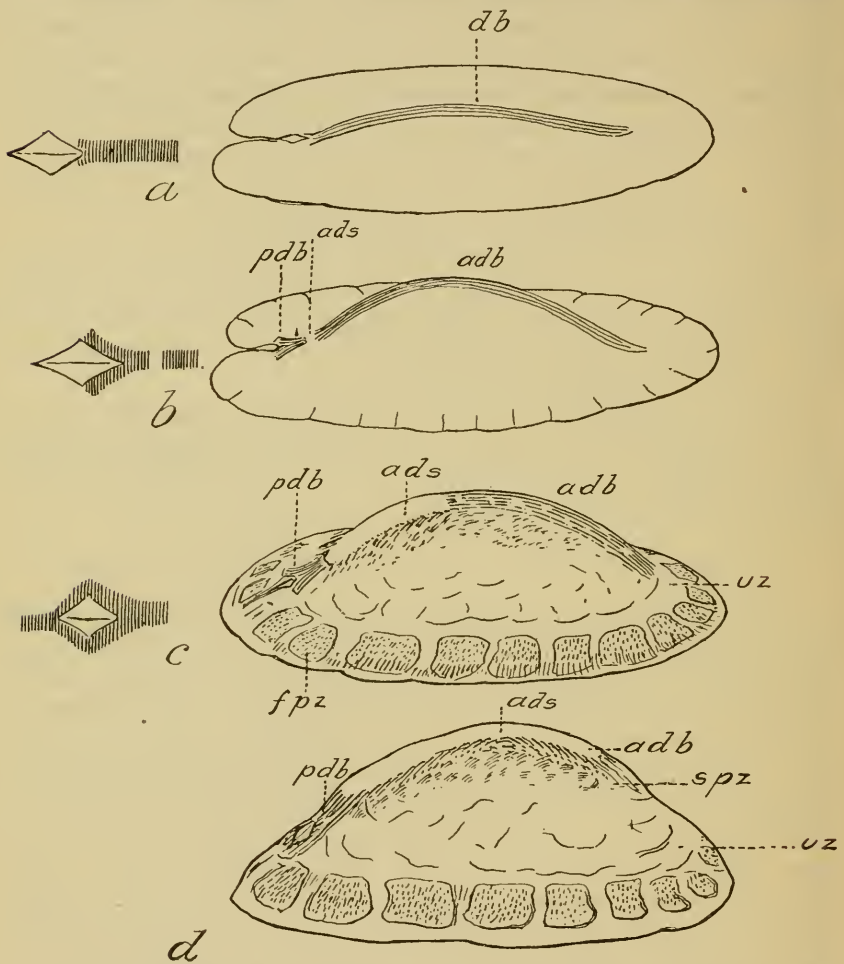


FIG. 15.—Diagrammatic representation of the color and markings of the female terrapin scale: *a*, Larva, seventh day upon the twig; *b*, larva, eleventh day upon the twig; *c*, larva, fifteenth day upon the twig; *d*, larva, twentieth day upon the twig and after; *db*, dorsal band; *adb*, anterior segment of dorsal band; *pdb*, posterior segment of dorsal band; *fpz*, first pigment zone; *spz*, second pigment zone; *ads*, adult dorsal stripe; *uz*, unpigmented zone. (Original.)

band. At the ninth day the female is about equally adult and larval in appearance. At this time the pale yellow body color of the larva begins to turn to a reddish amber and the characteristic crimps at the margin of the derm (fig. 15, *b*) begin to appear. In the depressions formed by the crimping, a brownish pigment develops and marks

them in sharp contrast with the narrow ridges of the crimps. These pigmented depressions blending form the first pigment zone or marginal pigmentation. (Fig. 15, *fpz.*) By the fourteenth day the female has become decidedly adult, both in shape and color. The first pigment zone now reaches completely around the dorsum and extends upward as far as the anal plates; the dorsal band has blended with the reddish-brown ground color, and a second zone of pigmentation has formed about the rent in the original dorsal band, thus transforming it into the permanent reddish-brown stripe which is so characteristic of the mature female. (Fig. 15, *ads.*) The second zone of pigment is composed of dark-brown granules similar to those in the marginal region. It surrounds the amber-colored gap in the original dorsal band and extends downward and outward nearly to the marginal zone, from which it is separated by an irregular unpigmented zone (fig. 15, *uz*) which lies parallel to the edge of the dorsum at about the height of the anal plates. By the twentieth day the female has assumed both the characteristic shape and color of the adult, but the general color is not so bright as in the case of older specimens. After the twentieth day there is no change in the color pattern. The pigmentation, however, deepens and the insect continues to grow, but at a decreasing rate, until it hibernates.

The data in Table XXVII show in detail the development of the female up to and including the fifteenth day after attaching to the twig. A very rapid growth is also shown during this period. The ground color changes from light yellow to reddish brown; the dorsal band develops and breaks and the adult pigmentation starts.

To obtain more extended observations upon the twig-attached females, 100 larvæ were taken August 15, 1913, while making the twigward migration, and placed upon a vigorous potted peach tree. This tree was kept under orchard conditions and such of the specimens as had accessible locations were numbered and observed from time to time through a Zeiss binocular. These observations were continued to the sixty-seventh day after migrating. Data from these specimens are given in Table XXVIII; they supplement Table XXVII.

TABLE XXVII.—*Details of the growth of the female terrapin scale during the first 15 days upon the twig, Mont Alto, Pa., 1913.*

No.	Original symbol.	Emerged.	Observed.	Age.	Period on twig.	Length.	Width.	General body color.	Dorsal band.	Anal Y.	Edge crimped.	Adult pigmentation.
				Days.	*Days.*	*Mm.*	*Mm.*					
1	A 1″	June 24	Aug. 7	44	1	1.625	1.1	Light yellow	Just starting	None	Not	None.
2	A 2″	...do	...do	44	1	1.65	.975	...do	...do	...do	...do	Do.
3	A 3″	...do	Aug. 6	44	1	1.525	1.1	...do	...do	...do	...do	Do.
4	B 10″	...do	Aug. 8	45	2	1.75	1.2	...do	Half completed	...do	...do	Do.
5	B 11″	...do	...do	45	2	1.675	1.075	...do	...do	...do	...do	Do.
6	B 12″	...do	...do	45	2	1.525	1.15	...do	...do	...do	...do	Do.
7	B 12″	...do	Aug. 11	48	2	1.35	.925	...do	One-fourth	...do	...do	Do.
8	A 3″	...do	Aug. 10	47	4	1.75	1.15	...do	Nearly	...do	...do	Do.
9	1″	...do	Aug. 13	50	4	1.475	.95	...do	Complete	...do	...do	Do.
10	A 2″	...do	Aug. 10	47	4	1.75	1.1	...do	...do	...do	...do	Do.
11	4	...do	Aug. 11	48	5	1.375	1.025	...do	...do	...do	...do	Do.
12	B	...do	Aug. 13	50	7	1.675	1.025	...do	One-fourth	...do	...do	Do.
13	A 2″	...do	...do	50	7	1.775	1.125	...do	Complete	...do	...do	Do.
14	4	...do	...do	50	7	1.375	.975	...do	...do	Forming	...do	Do.
15	C	...do	Aug. 14	51	8	1.65	1.05	...do	...do	...do	...do	Do.
16	D	...do	...do	51	8	1.35	1.00	...do	...do	...do	...do	Do.
17	2	...do	Aug. 11	48	8	1.85	1.275	...do	...do	...do	...do	Do.
18	3	...do	...do	48	8	2.00	1.5	...do	...do	...do	...do	Do.
19	2	...do	Aug. 13	50	10	1.85	1.3	...do	...do	Formed	...do	Do.
20	3	...do	...do	50	10	1.9	1.425	Reddish yellow	...do	...do	Crimped	Do.
21	A	...do	Aug. 14	51	11	1.875	1.475	Reddish brown	Broken	...do	Slightly	First zone forming.
22	B	...do	...do	51	11	1.95	1.55	...do	...do	...do	Not	None.
23	C	...do	Aug. 18	55	12	1.8	1.225	...do	...do	...do	...do	Do.
24	B	...do	...do	55	12	1.5	1.125	...do	...do	...do	Crimped	First zone advanced.
25	E	...do	...do	55	15	1.8	1.45	...do	...do	...do	...do	First zone forming.
26	B	...do	...do	55	15	2.00	1.55	...do	...do	...do	...do	First zone advanced.

TABLE XXVIII.—*Growth and color changes of female terrapin scales from the fourth to the sixty-seventh day after the twigward migration, Mont Alto, Pa., 1913.*

Observation No.	Number of specimens observed.	Date observed.	Period on twig.	Length.	Width.	Height.	General body color.	Degree of completion of the dorsal band.	Condition of the dorsal band.	Degree of completion of the anal band.	Condition of edge.	Amount of pigmentation as in adult.
			Days.	*Mm.*	*Mm.*	*Mm.*						
1	1	Aug. 19	4	1.525	1.125		Light yellow	Three-fourths	Unbroken.	Incomplete	Uncrimped	None.
2	2	...do	4	1.575	.925		...do	Nearly	...do	...do	...do	Do.
3	3	...do	4	1.525	1.05		...do	...do	...do	...do	...do	Do.
4	4	...do	4	1.7	1.15		Turning amber	Three-fourths	...do	...do	Slight crimp	Do.
5	7	...do	4	1.8	1.15		Light yellow	Nearly	...do	...do	Uncrimped	Do.
6	8	...do	4	1.72	1.15		...do	Incomplete	...do	...do	...do	Do.
7	9	...do	4	1.7	1.15		...do	Complete	...do	...do	...do	Do.
8	10	...do	4	1.75	1.075		...do	Incomplete	...do	...do	...do	Do.
9	11	...do	4	1.6	1.15		...do	Nearly	...do	...do	...do	Do.
10	12	...do	4	1.6	1.05		...do	...do	...do	...do	...do	Do.
11	13	Aug. 20	5	1.575	1.2		...do	Complete	...do	...do	...do	Do.
12	14	...do	5	1.6	1.1		...do	...do	...do	...do	...do	Do.
13	15	...do	5	1.625	1.075		Light amber	...do	...do	...do	Slight crimp	Do.
14	16	...do	5	1.575	1.00		Light yellow	...do	Breaking	...do	...do	Do.
15	17	...do	5	1.575	1.00		...do	...do	Unbroken	...do	Slight crimp	Do.
16	8	...do	5	1.75	.95		...do	...do	Breaking	...do	...do	Do.
17	20	...do	5	1.625	1.50		...do	...do	...do	...do	...do	Do.
18	21	...do	5	1.6	1.025		...do	Incomplete	Unbroken	...do	Uncrimped	Do.
19	22	...do	5	1.55	.925		...do	Three-fourths	...do	...do	...do	Do.
20	1	Aug. 23	8	1.6	1.1		...do	Complete	Broken	...do	...do	Do.
21	2	...do	8	1.70	1.075		Amber color	...do	...do	Complete	Slight crimp	Do.
22	3	...do	8	1.525	1.05		Light color	...do	Breaking	Partly complete	...do	Do.
23	4	...do	8	1.725	1.275		Reddish amber	...do	Broken	One-half complete	...do	Do.
24	7	...do	8	1.9	1.325		...do	...do	...do	One-fourth complete	...do	Do.
25	8	...do	8	1.75	1.275		Light amber	...do	...do	Nearly complete	...do	Do.
26	9	...do	8	1.7	1.175		Light yellow	...do	...do	Complete	Uncrimped	Do.
27	11	...do	8	1.625	1.225		...do	...do	Breaking	Incomplete	...do	Do.
28	12	...do	8	1.65	1.15		Reddish amber	...do	Broken	Complete	Slight crimp	Trace.
29	13	...do	8	1.625	1.255		...do	...do	...do	...do	...do	Do.
30	14	...do	8	1.75	1.125		...do	...do	...do	...do	Crimped	One-half first zone.
31	15	...do	8	1.625	1.150		...do	...do	...do	...do	...do	Do.
32	16	...do	8	1.75	1.125		Light yellow	...do	...do	Partly complete	Uncrimped	None.
33	1	Aug. 26	11	1.65	1.20		Reddish amber	...do	...do	Complete	Crimped	Evident.
34	2	...do	11	1.725	1.12		...do	...do	...do	...do	...do	Do.
35	7	...do	11	1.925	1.325		...do	...do	...do	...do	Slight crimp	None.
36	8	...do	11	1.75	1.375		Light amber	...do	...do	...do	Crimped	First zone.
37	14	Aug. 29	14	2.075	1.5		...do	...do	...do	...do	...do	First and second zones.
38	15	...do	14	1.85	1.2		...do	...do	...do	...do	...do	First zone complete.
39	16	...do	14	1.875	1.5		...do	...do	...do	...do	...do	Do.

TABLE XXVIII.—*Growth and color changes of female terrapin scales from the fourth to the sixty-seventh day after the twigward migration, Mont Alto, Pa., 1913*—Continued.

Observation No.	Number of specimens observed.	Date observed.	Period on twig.	Length.	Width.	Height.	General body color.	Degree of completion of the dorsal band.	Condition of the dorsal band.	Degree of completion of the anal band.	Condition of edge.	Amount of pigmentation as in adult.
			Days.	*Mm.*	*Mm.*	*Mm.*						
40	17	Aug. 29	14	1.875	1.25		Light amber	Complete	Broken	Complete	Crimped	Slight.
41	18	...do	14	1.925	1.375		...do	...do	...do	...do	...do	First and second zones.
42	21	...do	14	1.8	1.2		...do	...do	...do	...do	...do	None.
43	22	...do	14	1.65	1.25		Reddish amber	...do	...do	...do	...do	First zone.
44	23	...do	14	2.05	1.375		...do	...do	...do	...do	...do	Do.
45	1	Sept. 3	19	2.00	1.5		...do	...do	...do	...do	...do	First and second zones.
46	2	...do	19	1.96	1.49		...do	...do	...do	...do	...do	Do.
47	3	...do	19	1.913	1.588		...do	...do	...do	...do	...do	Do.
48	4	...do	19	1.96	2.05		...do	...do	...do	...do	...do	Do.
49	7	...do	19	2.146	1.866		...do	...do	...do	...do	...do	Do.
50	9	...do	19	2.05	1.68		...do	...do	...do	...do	...do	Do.
51	11	...do	19	1.866	1.68		...do	...do	...do	...do	...do	Do.
52	12	...do	19	2.05	1.726		...do	...do	...do	...do	...do	Do.
53	14	...do	19	2.24	1.68		...do	...do	...do	...do	...do	Do.
54	15	...do	19	1.96	1.493		...do	...do	...do	...do	...do	Do.
55	16	...do	19	2.053	1.54		...do	...do	...do	...do	...do	Do.
56	17	...do	19	2.006	1.493		...do	...do	...do	...do	...do	Do.
57	18	...do	19	2.05	1.49		...do	...do	...do	...do	...do	Do.
58	21	...do	19	1.963	1.4		...do	...do	...do	...do	...do	Do.
59	22	...do	19	1.773	1.31		...do	...do	...do	...do	...do	Do.
60	23	...do	19	1.96	1.493	0.615	...do	...do	...do	...do	...do	Do.
61	1	Oct. 21	67	2.035	1.677		...do	...do	...do	...do	...do	Complete.
62	2	...do	67	2.035	1.76	.66	...do	...do	...do	...do	...do	Do.
63	3	...do	67	2.035	1.76	.66	...do	...do	...do	...do	...do	Do.
64	4	...do	67	2.255	1.97	.66	...do	...do	...do	...do	...do	Do.
65	7	...do	67	2.2	2.15	.66	...do	...do	...do	...do	...do	Do.
66	11	...do	67	1.98	1.705	.55	...do	...do	...do	...do	...do	Do.
67	12	...do	67	2.09	1.87	.715	...do	...do	...do	...do	...do	Do.
68	15	...do	67	2.145	1.65	.715	...do	...do	...do	...do	...do	Do.
69	16	...do	67	2.145	1.651	.517	...do	...do	...do	...do	...do	Do.
70	18	...do	67	2.09	1.705	.66	...do	...do	...do	...do	...do	Do.
71	21	...do	67	2.145	1.595	.495	...do	...do	...do	...do	...do	Do.
72	22	...do	67	1.925	1.54		...do	...do	...do	...do	...do	Do.
73	23	...do	67	2.145	1.65	.66	...do	...do	...do	...do	...do	Do.

The Female Upon the Twig: Rate of Growth.

To determine the relative rate of growth of females after attaching to the twigs Table XXIX was compiled from the data obtained in 1913. This shows an increase from attachment on the twigs to the sixty-seventh day of 500 per cent in height and a pronounced increase in length and width. It is evident from this table that nearly all the growth takes place during the first 19 days.

Table XXIX.—*Size of twig-attached females of the terrapin scale after the specified days upon the twigs, Mont Alto, Pa., 1913.*

Date.	Number of specimens.	Period on twig.	Average length.	Average width.	Average height.
		Days.	*Mm.*	*Mm.*	*Mm.*
Aug. 1...	10	(1)	1.542	1.03	0.125
Aug. 7...	3	1	1.600	1.058	.....
Aug. 8...	3	2	1.65	1.141	.....
Aug. 19..	10	4	1.649	1.297	.208
Aug. 20..	10	5	1.619	1.226	.....
Aug. 23..	13	8	1.686	1.177	.....
Aug. 26..	4	11	1.762	1.25	.....
Aug. 29..	8	14	1.887	1.331	.....
Sept. 3...	13	19	1.996	1.592	.615
Oct. 21...	16	67	2.057	1.680	.625

[1] Just attached.

The Female Upon the Twig: Movement After Attaching to the Twigs.

It is very doubtful whether the females ever reattach after the first week's sojourn upon the twigs. During the first few days specimens have been observed to move, but whether or not the proboscis had been inserted into the host is unknown. Efforts were made to determine this, but no data were obtained. However, observations made upon specimens attached to slowly drying twigs indicate that they do not change position after the eleventh day.

The Derm.

With the arching of the dorsum during the first week the flat wax scale which protected the female larva during the migration from leaf to twig scales off; meanwhile the exposed surface thickens and hardens until by the end of the week it is so rigid that it responds to the growth changes by crimping. This hardening and thickening of the dorsum which produces the hard shell-like derm is completed by the twenty-fifth day. The excretion of wax, however, continues and wax flakes can be found attached to the derm up to the time of death.

Honeydew.

The attachment of the females to the twigs marks the beginning of the maximum period of honeydew deposit. If it were not for the deposit at this time the honeydew would be of very little economic

importance. This period of excretion extends to the time of hibernation, but practically all the honeydew is deposited during the first 25 days.

The anal apparatus is specially adapted to the excretion of honeydew. The anal plates, which are situated near the posterior end of the derm, are so hinged at their anterior ends that they can be both elevated and separated. When in this position they expose the anal chamber which lies just below them. This chamber is bounded laterally by the body lobes and connects ventrally with the brood chamber, while a cloacal cavity extends forward, within which there is a retractile spindle-shaped rectum, at the distal extremity of which the anal aperture is located. It is surrounded by a fringe of eight filaments called the anal ring. During repose the rectum occupies the anterior part of the cloacal cavity, and the anal fringe, which is folded into a cylindrical mass, occupies the posterior part. When the scale is not excreting the anal cavity is empty and closed at the top by the lidlike anal plates. Preparatory to excretion the anal plates are elevated and separated; the rectum with its fringe is drawn backward from the cloacal cavity into the anal chamber, from which it is thrust through the opening between the elevated anal plates. Contraction of the muscular walls of the rectum causes the contents to ooze into the basket formed by the filaments of the anal ring, where it forms a bubble which is held in place upon the end of the rectum by the supporting filaments, much as a jewel is held in its setting. When the bubble is fully formed it bursts, hurling the liquid composing it in the form of minute drops to a distance of from 3 to 8 inches. Cohesion between the honeydew and the filaments of the fringe is very slight. As a result no honeydew remains upon the fringe after the bursting of the bubble. The rectum is always withdrawn and the anal cavity closed after each expulsion. The deposit of honeydew from the twig-attached females becomes noticeable in orchards during the first week in August and rapidly increases in amount during the remainder of the month. At Midvale, Pa., in 1913, the deposit was first noticed August 4. It was made by the few advanced females then upon the twigs. The amount excreted reached its maximum on August 23, after which the amount upon the trees remained nearly constant until the first week of September. The sooty fungus which develops upon this honeydew increases in abundance with the increased deposit, and by the end of August its black spores have transformed the transparent honeydew into a sooty paste. By the end of the first week in September the leaves, branches, and fruit are covered by a black film of dried honeydew and spores. In some cases the infestation is so severe that the soil under the tree is coated almost as thickly as the limbs. The deposit

appears at its worst upon varieties that ripen after September 1. A basket of sooty peaches, with two normal peaches for comparison, is shown in figure 16.

Hibernation.

The scales depend for protection during hibernation upon their protective coloration, their hard derm, and their waxy coating. The color, while conspicuous in detached specimens, blends so nicely with the color of the young twigs as to conceal them effectively. The hard derm protects them from birds and insect enemies, and the wax film protects the insect from rain, surface moisture, and scalecides by preventing their passing under the scale.

Fig. 16.—A basket of "sooty" peaches with two clean ones for contrast. (Original.)

Size during hibernation.

Eulecanium nigrofasciatum passes the winter as an impregnated female. The following measurements, which were taken from fresh specimens at Mont Alto, Pa., February 24, 1913, are typical for the hibernation period: Length, maximum 2.375 mm., minimum 1.80 mm., average 2.072 mm.; width, maximum 2.28 mm., minimum 1.79 mm., average 2.0308 mm.; height, maximum 1.1 mm., minimum 0.725 mm., average 0.9084 mm.

Position on twigs during hibernation.

This species when on peach locates exclusively upon the last three seasons' growth, and by far the largest number of specimens is found upon the earliest formed wood of the last growing season. (See Pl. III, figs. 1, 2.)

The females in 1912 continued more or less active until November 12, and they remained dormant until April. This made the hibernating period cover about 4½ months.

Mortality during hibernation.

Practically every normal female will pass the hibernation period safely unless some accident happens to the host. Specimens at Mont

Alto, Pa., during the winter of 1912–13 passed this period with a mortality of less than 10 per cent. At Midvale, Pa., during the winter of 1913–14, specimens upon poorly nourished trees had a mortality as high as 54 per cent. Neither birds nor other animals make a noticeable attack during hibernation, but there is a strong parasitic attack upon the young females before hibernation. This was especially noticeable during the first week in September.

DEVELOPMENT OF THE MALE.

Male Larva, Second Instar.

In this instar the elongation of the larva and the secretion of the puparium undoubtedly start immediately after the first molt, but it is usually five or six days before they can be detected. The male increases, as is shown in Table XXX, from an average length of 1.03 mm. to an average length of about 1.706 mm., and in width from an average of 0.421 mm. to an average of about 0.830 mm. There is also an appreciable increase in height.

Table XXX.—*Average measurements of the male terrapin scale in the second instar at various ages between the twenty-fifth and thirty-fourth days, at Mont Alto, Pa.*

Year.	Date emerged.	Age.	Number of specimens.	Average length.	Average width.
		Days.		*Mm.*	*Mm.*
1912	Aug. 9	25	1	1.031	0.468
1912	...do.....	26	2	1.218	.421
1913	June 24	30	14	1.628	.830
1912	Aug. 9	31	4	1.579	.642
1913	June 26	32	13	1.661	.809
1913	June 24	33	13	1.621	.813
1913	...do.....	34	8	1.706	.777

In 1912 the instar extended to the fortieth day, but practically all males had shrunk in preparation for the second molt by the thirty-fifth day.

The following table compares the measurements of 54 females in the second instar with 48 males of the same rearing, and shows that the females average 0.168 mm. wider and 0.111 mm. shorter than the males.

Table XXXI.—*Comparative measurements of male and female larvæ of the terrapin scale during the second instar, Mont Alto, Pa.*

Age.	Date emerged.	Number males.	Length of males.	Width of males.	Number of females.	Length of females.	Width of females.
Days.			*Mm.*	*Mm.*		*Mm.*	*Mm.*
30	June 24	14	1.628	0.830	7	1.507	0.982
32	June 26	13	1.661	.809	16	1.506	.937
33	June 24	13	1.621	.813	20	1.587	.978
34	...do.....	8	1.706	.777	11	1.575	1.012
	Total....	48	.....	.....	54	.....	.....
	Average.	.....	1.654	.807	.....	1.543	.975

The male larva stops growth one day before the second molt, after which it shrinks and tends to assume a cylindrical form. The amount of this shrinkage, as is shown, averages 0.16 mm. in length and about 0.137 mm. in width. As a result of this shrinkage the edges of the puparium extend beyond the larva like the eaves of a roof.

TABLE XXXII.—*Shrinkage of 13 male larvæ of the terrapin scale during the last day of the second instar, 1913.*

	July 27.	July 28.	Difference.
	Mm.	*Mm.*	*Mm.*
Average length	2.17	2.01	0.16
Average width	1.075	.9375	.1375

The author's observations indicate that both sexes make the second molt at the same time and that they spend the same number of days in the second instar.

THE PUPARIUM.

The puparium is a transparent protective covering under which the male passes the third, fourth, and part of the fifth instar. It is secreted by dorsal wax pores during the second instar (Pl. II, *a*, *e*), and has the same dimensions as the full-grown larva, but owing to the shrinking of the larva the puparium at the end of the second instar is the larger. This structure is held in place by elastic bands which extend from points upon its edges to the leaf below. The largest of these is attached directly in front of the head. The ornamentation of the puparium consists of 2 longitudinal lines, 3 cross-lines, and a spear-shaped notch, which coincide in position at the time of its secretion with the anal plates and anal cleft of the larva. The longitudinal lines extend from the anterior end of the anal notch in mildly diverging curves anteriorly to a termination on the lateral edges near the position of the eye-spots of the larva. The cross lines, which are broken, are located at the middle and on the anterior and posterior thirds.

In this species the puparium is always placed upon the underside of the leaf (Pl. III, fig. 3) and never upon the twigs. In this it differs from *Eulecanium corni* Bouché, which frequently has puparia upon the twigs. Twenty-four puparia taken at Mont Alto, Pa., during 1912, had the following sizes: Length, maximum 1.725 mm., minimum 1.443 mm., average 1.641 mm.; width, maximum 0.825 mm., minimum 0.54 mm., average 0.707 mm. The puparia of 1913 in the same orchard were slightly larger; 13, measured July 28, averaged in length 1.706 mm. and in width 0.778 mm.

Second Molt of the Male.

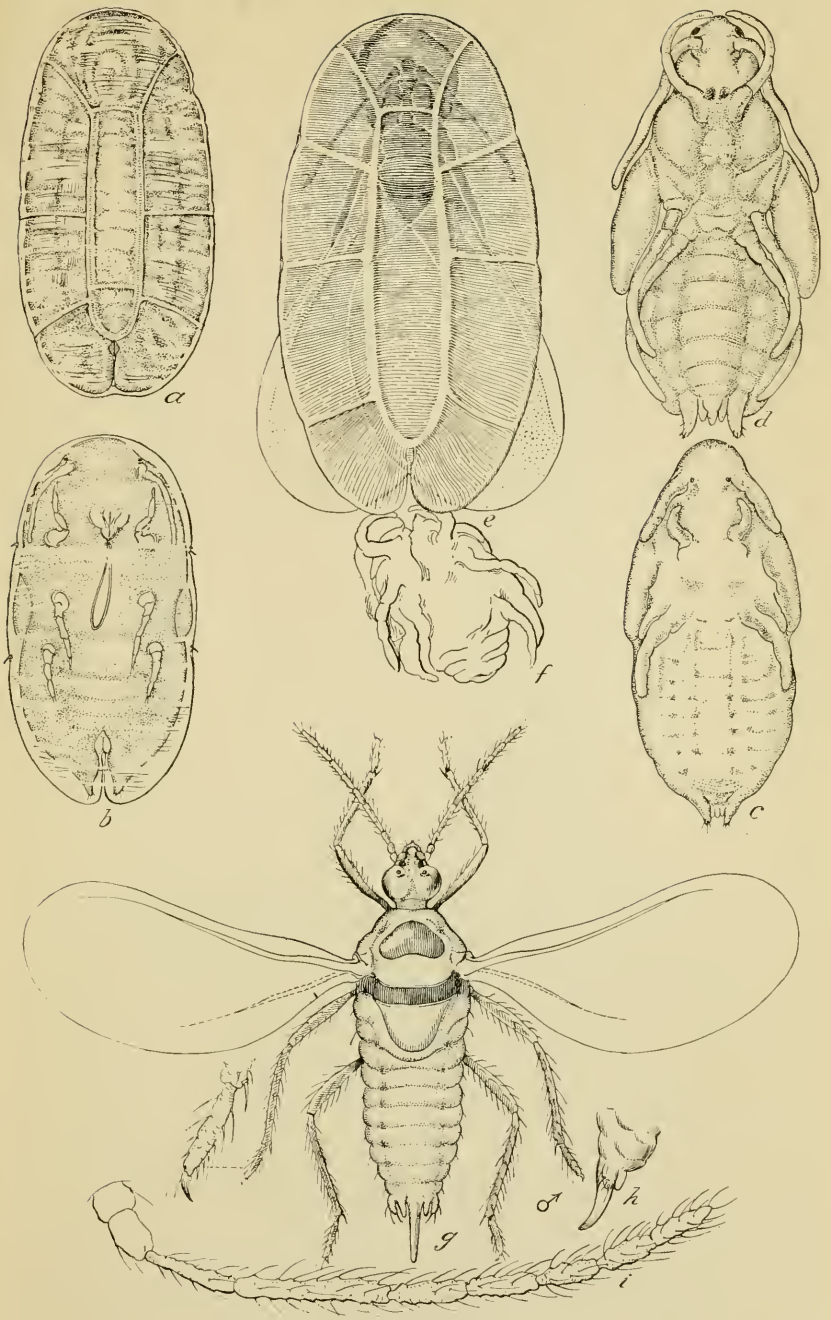
In 1912 the second molt was made by orchard larvæ from the thirty-eighth to the forty-third day, with its maximum upon the forty-first day, after emergence from the brood chamber. In 1913, with a more favorable season, this molt was made by orchard larvæ upon the thirty-sixth day. Since the larvæ entered the second instar upon the eighteenth day, they averaged 18 days in the second instar. Two rearings were made in 1913, the first from larvæ that emerged June 24 and the second from larvæ that emerged June 26. The former made their maximum daily molt for both sexes upon the thirty-seventh day, the latter upon the thirty-fourth day.

When the male larva shrinks at the end of the second instar the larval skin retains its original shape and position (Pl. II, *b*). This leaves the larva nearly free within. At this time a decided metamorphosis begins. The original legs, antennæ, and mouth-parts disappear and the anal lobes, which in the second instar are one-half as wide as the body and extend caudad beyond the anal plates (Pl. II, *a*), now shrink to short, narrow projections which extend only slightly beyond the anal plates. As a result of this change in the anal lobes the anal crease disappears and the anal apparatus assumes again its original position on the caudal margin. During this metamorphosis the hard portions of the mouth-parts remain attached to the larval skin and disappear at the second molt, after which all trace of the mouth-parts is lost. In the act of molting the larval skin is ruptured by contortions of the larva along the middorsal line, and in a few minutes it is worked downward and backward and is expelled at the caudad margin of the puparium, where it usually remains for a few days clamped under the puparium.

The Prepupa.

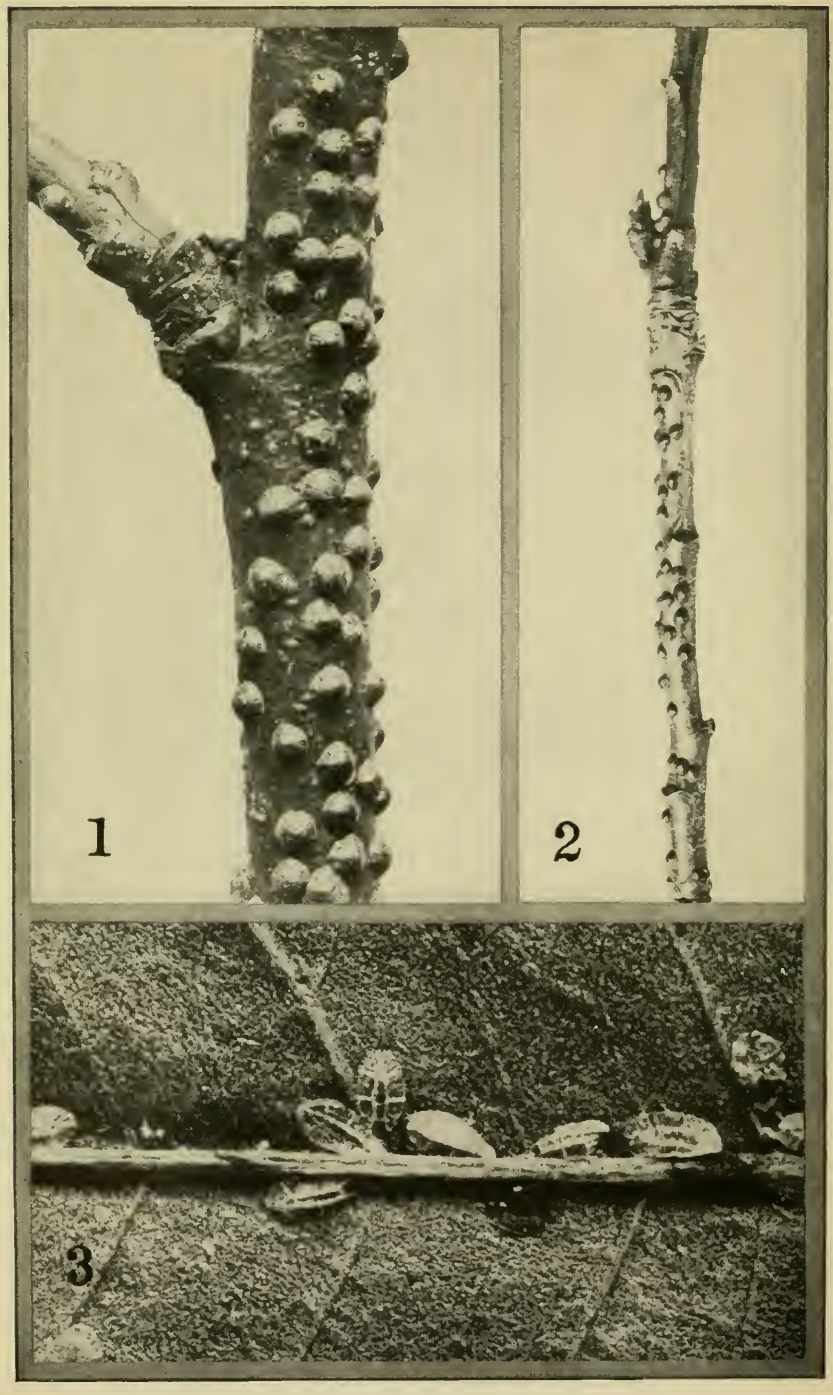
The prepupal instar is characterized by a rapid metamorphosis, which, however, actually starts before the casting of the second molt skin. The plump anal lobes of the first and second instars shrink, and the characteristic anal plates (Pl. II, *a*) are lacking. The most evident characters at the beginning of the instar are the wing-pads and the pointed anal lobes.

The prepupal period covers but 2 days, yet the metamorphosis is so rapid that decided changes occur. The wing-pads expand to their full size; the antennal sheaths expand from buds to nearly one-half of their final length, and the leg sheaths, which at the beginning of the instar were indicated by imaginal buds, become one-fourth developed. The metamorphosis of the anal region continues throughout this instar and at its end all trace of the conspicuous anal plates is lost. In their place there now project from the caudal extremity two



THE TERRAPIN SCALE.

a, The second instar under the puparium; *b*, same, shrinking in the last day of the second instar; *c*, prepupa; *d*, pupa; *e*, imago before emergence; *f*, pupa case clamped under the puparium; *g*, imago at twigward migration; *h*, lateral view of caudal extremity; *i*, enlarged antenna. All much enlarged. (Original.)



THE TERRAPIN SCALE.

FIG. 1.—Appearance of the scale on peach twig during winter; somewhat enlarged. FIG. 2.—Same, about natural size. FIG. 3.—Male puparia along midrib of peach leaf; considerably enlarged. (Original.)

fleshy lobes, between which are the sheaths of the copulatory apparatus. (Pl. II, *c*.) The ventral eyes are represented at the end of this instar by two brown spots.

This instar is quite constant in its length, being almost invariably 2 days. Table XXXIII gives data upon 18 males from the rearing of June 24, 1913. The average length was 2 days.

TABLE XXXIII.—*Average duration of the prepupal instar for 18 specimens of the terrapin scale, Mont Alto, Pa., 1913.*

No.	Date of second molt.	Date of third molt.	Time in prepupa.	No.	Date of second molt.	Date of third molt.	Time in prepupa.
			Days.				*Days.*
1	July 31	Aug. 2	2	11	July 31	Aug. 3	3
2	Aug. 4	Aug. 6	2	12	July 30	Aug. 1	2
3	July 31	Aug. 2	2	13	July 31	...do	1
4	July 30	Aug. 1	2	14	July 29	July 31	2
5	...do	...do	2	15	Aug. 1	Aug. 3	2
6	...do	...do	2	16	...do	...do	2
7	...do	Aug. 2	2	17	Aug. 5	Aug. 7	2
8	...do	Aug. 1	2	18	Aug. 4	Aug. 6	2
9	Aug. 1	Aug. 3	2				
10	July 31	Aug. 2	2	Average			2

Larvæ that emerge upon the same day may vary as much as 10 days in the time required for them to reach the prepupa. The normal time of entering this instar, however, is clearly defined for most individuals. One-half of the males in any rearing will ordinarily become prepupæ upon the same date. The normal time for entering this instar in the region about Mont Alto, Pa., is upon the thirty-eighth day after emerging from under the parent scale.

Prepupæ were abundant in the orchard at Mont Alto, Pa., in 1912, from August 8 to August 20. They were present in largest numbers about August 12; after this they became gradually less abundant until August 25. After August 25 they were very scarce. At Midvale, Pa., in 1913, the first prepupæ were taken July 18. At Mont Alto, Pa., in 1913, the first prepupæ were taken July 24. This is 5 days earlier than they appeared at Mont Alto the preceding year.

Since both sexes made the second molt at the same age, and since the females migrate twigward upon the second day after this molt, it happens that the twigward migration of the females coincides with the prepupal instar of the male. In 1912 the first returned females—6 specimens in all—were taken July 29. While there were undoubtedly as many prepupæ as returned females at this time upon the trees, none was found. By August 2 the number of returned females had greatly increased and, upon this date, the first prepupæ of the season were taken.

There was a difference in 1913 of 6 days in the appearance of prepupæ at the Wertz and in the Newcomer orchards. This was due to the difference in the localities. The Wertz orchard has a strong

westward slope and is located at an altitude of 1,100 feet, with a mountain crest extending 1,000 feet above it. There is consequently a good air drainage and a partial exclusion of the sun's rays during the forenoon. The Newcomer orchard, upon the other hand, is located upon a slight knoll, with relatively level surroundings. Its altitude is less than 900 feet. Consequently the air drainage is not good and the sun's rays are unobstructed.

Four prepupæ were measured in 1912, with the following results: Length, maximum 1.29 mm., minimum 1.08 mm., average, 1.208 mm.; width, maximum, 0. 618 mm., minimum, 0. 562 mm., average, 0.587 mm. On April 28, 1913, 8 specimens gave the following measurements: Length, maximum 1.420 mm., minimum 1.25 mm., average 1.33 mm; width, maximum 0. 6 mm., minimum 0. 525 mm., average 0.559 mm.

Third Molt.

The prepupa starts the third molt by a series of convulsive movements which cause the dorsal skin to split over the thoracic region. The skin is loosened and removed almost entirely by extending and contracting the abdomen. The extension thrusts cause a tension upon the ventral part of the molt skin which draws the head downward and under. This causes the dorsal thorax to protrude through the split in the molt skin. This tension increases with each thrust of the abdomen, so that the head is drawn farther and farther downward and backward until it finally slips free from the skin. The larva then assumes its regular position. In stripping the molt skin from the legs and antennæ the thrusting movements of the abdomen are aided by the puparium, which, owing to its attachment with elastic bands, yields to the molting movements and serves as a clamp to hold the skin in place while the abdomen contracts for the next thrust. The thrusting movements of the abdomen usually cease before the skin is completely expelled from under the puparium. Because of this the cast skins are mostly found clamped under the posterior end of the puparium.

The duration of this molt varies with the temperature at the time of molting and also with the vigor of the specimen. The molt usually starts in the forenoon with the resumption of the daily activity. The average time for this molt is less than an hour. Upon days when the temperature reaches 70° F. before 9 a. m., practically all the molts for the day will be completed by 10 a. m. At low temperatures many specimens die without completing it. Some specimens kept in the laboratory where the temperature did not rise above 70° F. required 18 hours for this molt. They started molting about 4 p. m. and became dormant before completing it. These molts were completed the following day.

The Pupa.

The pupal instar is one of development. In it the rudimental structures of the preceding instar reach their full development. The leg sheaths are mere tubes at the beginning of the instar; at the end they contain the matured legs. The wing sheaths have a similar history, being at first transparent bags, which develop gradually until the last third of the instar, when the wings fold and the characteristic fleshy color appears. The pupa (Pl. II, *d*) has a pale flesh color with chitinized areas upon the head and anal region. There is also a crescent-shaped spot and a transverse band of a bright flesh color. The antennæ and legs are at first ventral, but they elongate and finally appear prominently in the dorsal view.

TIME IN PUPA.

The pupal instar varies in length, occupying from 4 to 11 days, and averages about 6 days in favorable weather. Those individuals that spend only 4 days in this instar have invariably been delayed as prepupæ. It is very exceptional for a male to pass 8 days in the pupa, even when weather conditions are unfavorable. When conditions are such that the pupæ require over 9 days, there is a heavy mortality. Many die, and those that enter the adult stage mostly die without leaving the protection of the puparium.

In both 1912 and 1913 rearings were made to determine the length of the pupal period under varying conditions. Observations made upon the specimens in the orchard showed that most of the specimens remained in the pupa 6 days. A brood that emerged July 22, 1912—that is, approximately a month after the height of the normal emergence—was retarded 6 days by unfavorable conditions. Thirteen males passed successfully through the pupal stage and gave an average of 8.15 days in the pupal instar.

The average mean temperature for July, August, and September, 1912, was 71.5° F.

A brood that emerged June 24, 1913—that is, appproximately at the height of emergence—passed through the larval instars in a normal manner, and the imagos left the puparia upon the forty-sixth day. These specimens were slightly retarded, owing to their removal while in prepupa from the orchard to the laboratory. Fourteen of these specimens passed through the pupal instar in a normal manner. They gave an average of 6.2 days for the pupal instar. The fraction of a day in excess of 6 days is small and is clearly due to the unfavorable environment of the laboratory. Table XXXIV gives the individual record of these 14 males. The average mean temperature for June, July, and August, 1913, was 73.4° F.

TABLE XXXIV.—*Length of the pupal instar of the terrapin scale for larvæ that emerged June 24, 1913, Mont Alto, Pa.—Conditions favorable.*

No.	Date entered.	Date left.	Pupal stage.	No.	Date entered.	Date left.	Pupal stage.
			Days.				*Days.*
1	Aug. 2	Aug. 10	8	9	Aug. 2	Aug. 9	7
2	...do...	Aug. 8	6	10	Aug. 1	Aug. 8	7
3	Aug. 1	...do...	7	11	July 31	Aug. 5	5
4	...do...	Aug. 7	6	12	...do...	Aug. 6	6
5	...do...	Aug. 8	7	13	Aug. 3	Aug. 8	5
6	Aug. 2	...do...	6	14	Aug. 1	Aug. 7	6
7	Aug. 1	Aug. 5	4				
8	Aug. 3	Aug. 10	7	Average			6.2

APPEARANCE OF PUPÆ IN THE ORCHARD.

Pupæ appear in the orchard upon the second day after the females start migrating to the twigs, and they are most abundant about the sixth day after the maximum daily migration.

At Mont Alto, Pa., 80 per cent or more of the males pass through the pupal state during the first half of August.

SIZE OF PUPÆ.

The pupæ are slightly smaller than the prepupæ, but owing to the great size of the wing-pads the pupæ average slightly wider.

Table XXXV gives measurements for 20 specimens, the first 10 of which were from 1912 and the remainder from 1913. The sizes are quite uniform for the two seasons and average 1.248 mm. long and 0.5918 mm. wide. A comparison of the prepupal and pupal measurements from the same individuals shows an average decrease in length of 0.09 mm. and an increase of 0.03 mm. in width in passing into the pupal instar.

TABLE XXXV.—*Measurements of 20 mature pupæ of the terrapin scale, Mont Alto, Pa., 1912 and 1913.*

No.	Length.	Width.	No.	Length.	Width.	No.	Length.	Width.
	Mm.	*Mm.*		*Mm.*	*Mm.*		*Mm.*	*Mm.*
1	1.2250	0.55	9	1.1000	0.600	16	1.250	0.650
2	1.3375	.575	10	1.2500	.625	17	1.175	.575
3	1.2750	.550	11	1.325	.625	18	1.275	.650
4	1.3000	.600	12	1.250	.475	19	1.250	.625
5	1.3000	.550	13	1.250	.650	20	1.250	.600
6	1.2500	.600	14	1.250	.550			
7	1.2500	.562	15	1.200	.600	Average	1.2481	.5918
8	1.2000	.625						

FOURTH MOLT.

The fourth molt, like the third, usually starts in the morning when the temperature rises to about 70° F. The first indication that a molt is about to start is a series of convulsive movements. These cause the thin pupa case to split along the anterior third of the mid-dorsal line. As these movements continue the dorsal thorax pro-

trudes more and more through this slit and the head is forced downward. Before the head escapes the anterior legs are withdrawn from their sheaths. These are the first appendages to become free. They push the case downward until the head is free. After this they force the case backward under the body. The antennal sheaths cling tightly to the antennæ and have to be stripped free from them. The middle and posterior legs take no active part in the molt, but lie motionless along the edges of the abdomen. The antennal sheaths are the last parts of the case to be shed. After the head escapes from the case it presses against the anterior end of the puparium, which serves as a fulcrum in forcing the adult free from the pupa case. Pupæ that escape by accident or are removed from under the puparium are unable to complete the molt. They continue the effort for about 24 hours and then die. In the case of weak specimens the impulse to molt often ceases before the tips of the antennæ are free. After this molt the pupal case is usually found lightly clamped under the posterior edge of the puparium. (See Pl. II, *f*.)

This molt ordinarily requires about 2 minutes for specimens at temperatures above 70° F., but at a temperature of 66° F. the time required is 5 minutes. This molt should take place about the forty-seventh day, but it is frequently delayed. For example, part of a brood that emerged August 9, 1912, was removed from the trees when in pupa. They were placed in the laboratory late in September, away from heat and sunlight, and under these conditions many of the specimens died. The remainder were abnormal and did not molt until the fifty-fifth day, or 8 days after the natural time. It was evident that a slightly longer delay would have resulted in the death of all the specimens in the pupa or during the molt.

The Adult Male.

The fourth molt, like the third, is made under the puparium. The young imago at first has soft and folded wings, but these soon assume their natural shape. Several hours, however, are required for them to harden and to become fully colored. After expanding they protrude slightly from under the posterior end of the puparium and serve as a means of identifying this stage. The time spent under the puparium varies from a few hours to 4 days. The normal time for the male to remain under the puparium is from 1 to 2 days. The male regularly enters the imago in the forenoon of one day and emerges during the afternoon of the following day, but there are well-defined exceptions to this. If favorable weather has so accelerated the growth as to shorten the preceding instars, the imago tends to remain under the puparium until the regular time for emerging, but when the early instars are lengthened by unfavorable weather the imago emerges in less than 2 days.

In Table XXXVI are recorded data from 14 males that emerged late in the season of 1912. They had the fourth molt delayed to the fiftieth day and give an average of 1.36 days as the time spent under the puparium. Specimen No. 3 partly escaped from under the puparium during the fourth molt. It remained in this position for 4 hours and then emerged and started to leave the leaf.

TABLE XXXVI.—*Emergence of 14 males of the terrapin scale from a brood that made the fourth molt upon the fiftieth day, Mont Alto, Pa., 1912.*

No.	Fourth molt.		Emergence.		Time spent under puparium.	
	Date.	Time.	Date.	Time.		
					Days.	*Hrs.*
1	Sept. 5	8.40 a. m.	Sept. 6	8.40 a. m.	1	0
2	Sept. 9	10 a. m.	Sept. 10	10 a. m.	1	0
3	Sept. 11	6 a. m.	Sept. 11	10 a. m.		4
4	...do.	6 a. m.	Sept. 14	6 a. m.	3	0
5	Sept. 10	2 p. m.	Sept. 12	6 a. m.	1	16
6	Sept. 12	6 a. m.	...do.	6 p. m.		12
7	Sept. 11	12 m.	Sept. 14	9 a. m.	2	21
8	Sept. 12	1 p. m.	Sept. 13	6 a. m.	1	17
9	Sept. 11	2 p. m.	...do.	6 a. m.	1	16
10	Sept. 12	6 p. m.	...do.	6 a. m.		12
11	Sept. 11	12 m.	Sept. 12	6 a. m.		18
12	...do.	12 m.	...do.	6 a. m.		18
13	Sept. 10	9 a. m.	...do.	6 a. m.	1	21
14	...do.	3 p. m.	...do.	6 a. m.	1	15
Average					1	9.07

In Table XXXVII are recorded data from 12 imagos that emerged from the brood chamber June 24 and made the fourth molt upon the forty-fifth day. They were thus normal in development. They give an average of 2 days spent under the puparium. Eight specimens from this same brood were removed from the orchard 7 days before they emerged as imagos and placed upon glass plates in the laboratory. As a result of this treatment they were delayed in the pupal stage and spent only one day under the puparium, a reduction of one-half in the time due to the changed conditions.

TABLE XXXVII.—*Emergence of 12 males of the terrapin scale from a brood that made the fourth molt upon the forty-fifth day, Mont Alto, Pa., 1913*

No.	Date of fourth molt.	Imago emerged.	Time under puparium.	No.	Date of fourth molt.	Imago emerged.	Time under puparium.
			Days.				*Days.*
1	Aug. 10	Aug. 11	1	8	Aug. 10	Aug. 11	1
2	Aug. 8	Aug. 9	1	9	Aug. 8	Aug. 10	2
3	...do.	...do.	1	10	Aug. 7	...do.	3
4	July 7	Aug. 11	4	11	Aug. 5	Aug. 8	3
5	Aug. 8	Aug. 9	1	12	Aug. 8	Aug. 10	2
6	...do.	...do.	1				
7	Aug. 5	...do.	4	Average			2

A comparison of Tables XXXVI and XXXVII shows that the time spent under the puparium by the imago varies from 4 hours to 4 days and that the average time for normal development is 2 days.

Imagos were taken from under puparia in small numbers at Midvale, Pa., on July 27, 1913. These were the earliest specimens taken during the two seasons of observation.

EMERGENCE OF ADULT MALE.

The imago (Pl. II, *g*) usually leaves the puparium about the forty-ninth day. In 1912 the early part of the season was favorable and the imagos emerged upon the forty-ninth day, but later in the season males reared from larvæ that emerged from the brood chamber August 9 did not leave the puparium until the fifty-second day, with several specimens delayed until the fifty-eighth day. In 1913 the males emerged from the forty-third to the fifty-ninth day, with the maximum emergence upon the forty-ninth day.

DESCRIPTION OF ADULT MALE.

Length, exclusive of style, 1 mm.; style 0.15 mm.; caudal lobes 0.075 mm., being one-half as long as the paired lateral appendages; antennæ 0.6 mm.; wing, 0.44 mm. long, 0.3 mm. wide. Light flesh color in general. Head light flesh color; anterior pair of dorsal eyes reddish brown; posterior dorsal eyes similar and one-half as large; ventral pair dark brown and slightly larger than the anterior dorsal pair; antennæ whitish, 8-jointed, joint I short, thick, semiglobular; joint II slightly longer than I, claviform; joint III as long as both I and II, slender and cylindrical; the remaining joints cylindrical and subequal. Collar short cylindrical; prothorax narrow; dorsal mesothorax light flesh color, with a flesh-colored shield-shaped spot above, and terminated posteriorly by a narrow bright band of the same color; metathorax light flesh color. Wing iridescent, surface granulose, false vein through anal third; halteres none; caudal filments none; legs and style light brown.

TWIGWARD MIGRATION OF THE MALE.

The male backs out from under the puparium and at once starts for the twigs. The wings are not ordinarily used in this migration. The insect is attracted by strong light and seems to be guided somewhat in its movements by gravity and possibly also by the scent of the female. The males leave the underside of the leaf and pass down the petiole. When the twig is reached they turn downward and examine the surface carefully as they pass over it. The antennæ are held aloft and nearly motionless, but the anterior tarsi are kept in constant motion, tapping and feeling the surface of the twigs. The males frequently in their search pass to the tips of the twigs, and in such cases they may circle the twig a few times and then return to the base and pass on, but when the illumination is strong they alight upon other twigs and start again in active search. The interval between emerging and starting the active search for the female scales is very brief, being always less than 30 minutes. The male is sexually mature when he emerges. When he approaches a female he taps upon the derm with his anterior legs, usually passing several times around the specimen in doing so, or he may conduct the examination while upon the female's back. During such an

examination the male is often diverted and may move away, but he will return, again and again, before finally abandoning his efforts. Those females that have copulated are indifferent to the male, but females of the same age that have not copulated respond by elevating and distending the anal plates. After a preliminary examination of the dorsal surface of the female the male mounts and takes the copulating position, with the head forward and the body parallel to that of the female. In the act of copulation the abdomen is curved under until the tip is in contact with the anal plates. The act of copulation requires from 2 to 10 seconds, according to the degree of exhaustion of the male. At the end of copulation the male departs and continues his search for additional mates. If by chance he returns a second time to the same female his tappings bring no response. The male is decidedly polygamous and continues copulating with one female after another until he dies of exhaustion. The following observations were made upon a male that left the puparium September 6, 1913:

Emerged from puparium	9.40 a. m.
Discovered first susceptible female and copulated	9.42 a. m.
Discovered second female and copulated	9.44 a. m.
Discovered third female	9.46 a. m.
Discovered fourth female	9.50 a. m.
Discovered fifth female	9.56 a. m.
Died of exhaustion	9 p. m.

At the end of the fifth copulation detailed observations stopped, but the male continued in diligent search for more females. This individual died of exhaustion 12 hours after leaving the puparium.

The active male, when moving naturally upon the host plant, lives less than 24 hours. Almost invariably the male emerges in the forenoon, exhausts himself in copulation during the hottest portion of the day, and dies before midnight. When confined singly in test tubes they live from 1.25 to 2.75 days. Six specimens confined in test tubes gave 2.75 days as the maximum, 1.25 days as the minimum, and 1.625 days as the average longevity.

Summary of Life History of the Male.

The male lives an average of 49 days and passes through 5 instars. In the first two instars it is a vigorous feeder, and accumulates all the energy used during the remainder of its life. The 3 remaining instars are characterized, as a whole, by the absence of functional mouth-parts and by the development of the adult organs.

The length, in favorable weather, and the distinguishing characteristics of the instars are as follows.

The feeding instars: First instar, length 18 days—vegetative; second instar, length 18 days—sexual differentiation.

The nonfeeding instars: Third instar (prepupa), length 2 days—metamorphosis; fourth instar (pupa), length 6 days—development of adult structures; fifth instar (imago) dormant phase, length 2 days—hardening of exo-skeleton; active phase, length 1 day—migration and copulation.

SEASONAL HISTORY.

There is one generation of the terrapin scale annually. This species passes the winter as immature females. At the start of hibernation these are very plump and the ventral part of the abdomen crowds against the surface of the host, so that there is no vacant space beneath the scale, but by the middle of March the abdomen has shrunken until there is a dome-shaped cavity beneath it. When the spring growth starts the specimens become plump again and the space beneath the scale disappears. Most of the specimens reach maturity during the middle of June and begin at once to produce young. The majority of the scales reproduce for a period of about one month. but an occasional female may continue actively reproducing for as long as 3½ months. On the second day after the first young are born they begin to emerge from the brood chamber of the parent, mostly through the anal cleft. During the first 5 weeks there is a heavy migration of larvæ to the leaves. This migration reaches its maximum during the first week of emergence. It then gradually declines, until by the end of the fifth week it amounts to less than 5 per cent of the maximum emergence. (See figs. 2 and 4.) At the beginning of the sixth week after the appearance of the first young the female larvæ start migrating from leaf to twig. By the end of the seventh week the females are ready for copulation and the males migrate to the twigs. Copulation occurs at this time and the males die at once, but the females start upon a period of rapid growth, during which they excrete a vast amount of honeydew, which is responsible for most of the injury caused by this scale. After 2 or 3 weeks of extreme activity their growth gradually slackens, but it continues until cold weather forces the partly mature females into hibernation, after which they remain dormant until the following spring, dying about midsummer after the production of young.

MORTALITY.

There is more or less mortality at all seasons of the year. Ordinarily there seems to be comparatively little due to winterkilling, though at times this may be considerable. The amount of winterkilling depends mainly upon the vigor of the host plant and upon the severity of the winter. During 1912-13, upon well-nourished trees, the mortality from this source was not more than 5 per cent of the hibernating scales. During 1913–14, however, scales upon trees of low vitality had a mortality as high as 40 per cent.

The females during the spring development are sometimes heavily attacked by hymenopterous parasites, especially species of the genus Coccophagus. At the start of reproduction the larvæ of the coccinellid *Hyperaspis binotata* Say (fig. 17) enter the brood chambers and attack the lecanium larvæ, while later the maturing larvæ of this beetle, in attempting to enter the brood chambers, dislodge many of the gravid females, thus destroying at once both the female and the unborn young. (See fig. 18.)

Cold, wet weather at the time of reproduction causes many larvæ to die in the brood chamber. These frequently clog the exit and prevent the egress of the remainder of the brood. This condition was especially noticeable in the season of 1912, when owing to protracted rain 5 per cent of the gravid scales were affected in this way.

During the leafward migration most of the young succeed in reaching the leaves, and the loss at this period is due mainly to drowning by sudden rains and to the dropping of larvæ from dead twigs. During the leaf phase the larvæ are often heavily attacked by predatory enemies, but the female larvæ are practically free from parasitic attack, and the males are but slightly attacked. However, after returning to the twigs the females are subject, at times, to a heavy parasitic attack which may cause a mortality as high as 20 per cent. They are also subject to attack at this time by a pyralid moth, *Laetilia coccidivora* Comst. In conclusion it may be said that the mortaility from weather conditions throughout the year is not more than 50 per cent, and that in favorable seasons it is almost negligible.

ATTENDANTS.

The terrapin scale excretes a honeydew which is very attractive to ants, and during the time in which it is being deposited all the species of ants in the vicinity will be found working upon it, while at other seasons no ants will be about. In the early spring, when the fruit buds are about to burst into bloom, considerable honeydew is excreted and ants are then actively working, but during the period of reproduction very few ants appear. When, however, the twigward migration of the females starts, the ants return and remain in almost constant attendance until the scale hibernates. There is no species of ant that habitually attends this scale, but most of the orchard ants feast upon its bounties. Only slight benefit to the scale results from the attendance of the ants. Some of them are pugnacious and undoubtedly tend to ward off predators and to frighten away and confuse parasites.

The following four species taken at Mont Alto, Pa., attending this scale were identified by Dr. W. M. Wheeler:

Formica truncicola Nyl. subsp. *integra* Nyl.
Formica fusca L. var. *subsericea* Say.
Lasius niger L. var. *americanus* Emery.
Prenolepis imparis Say.

PREDACEOUS ENEMIES.

At Mont Alto, Pa., in 1912, the lacewing fly *Chrysopa nigricornis* Burm. made an attack during the twigward migration which was unimportant, although it continued until the larvæ migrated to the twigs. This species was reported in 1893 by Mary E. Murtfeldt as actively attacking the larvæ of this lecanium.

Larvæ of *Hemerobius stigmaterus* Fitch were present in 1912 in considerable numbers and the result of their attack was quite noticeable.

The predaceous pyralid *Laetilia coccidivora* Comst. was present in 1913, and its larvæ made a very vigorous attack. The eggs were placed singly among the scales upon infested twigs, apparently during the first half of June, and hatched in about 6 days. The larva is greenish black, with a black, slightly bilobed head, and feeds within a delicate silken tube which it constructs from scale to scale as it advances along the twig. It first attacks the gravid females, and hundreds of their empty derms can often be seen clinging to one another and to the silken tubes upon trees where it has fed. When the larva reaches its full development it spins a cocoon within the silken tube, usually near the axil of a bud or at the base of a fruit spur. *L. coccidivora*, at Midvale, Pa., requires about 10 days to pass through the pupal stage. The imagos emerged from their cocoons during August and deposited their eggs upon the twigs among the young scales, which were at that time migrating to the twigs. The larvæ of this second brood made a vigorous attack upon the young females. This predator is aggressive and under favorable conditions can undoubtedly control this scale. The author observed its work during the season of 1913, in the orchard of Mr. A. Newcomer, near Midvale, Pa. It was, however, heavily parasitized, and so made very little impression upon its host. Two species of parasites were reared in abundance from this pyralid at Midvale, Pa. They were *Mesostenus thoracicus* Cress. and an undescribed species of Habrobracon.

The predatory bug *Camptobrochis nebulosus* Uhl., although not found at Mont Alto, Pa., was reported by Mary E. Murtfeldt as preying upon the active larvæ of this lecanium at Kirkwood, Mo., in 1893.

Species of Coccinellidæ of the genus Hyperaspis are undoubtedly the most efficient agents in the control of this lecanium. Miss Murtfeldt, in reporting upon *Hyperaspis signata* for 1893, says: "The flocculent larvæ of this coccinellid were very numerous and active among swarming larvæ of *L. nigrofasciatum* but were not found upon any other coccid or aphis during the season."

Mr. A. B. Gahan, in Maryland Agricultural Experiment Station Bulletin 149, mentions the attack by ladybirds and says: "* * * the species most commonly observed being the twice-stabbed lady-

bird, *Chilocorus bivulnerus*." The writer has occasionally taken the adults of this species, which is scarce about Mont Alto, Pa., upon trees infested with the terrapin scale, but has never observed either it or its larvæ preying upon this scale.

FIG. 17.—A predaceous enemy of the terrapin scale, *Hyperaspis binotata*. Much enlarged. (Original.)

At Mont Alto, Pa., there was, in 1912 and 1913, a heavy and effective attack by *Hyperaspis binotata* Say. This ladybird was taken abundantly in the orchard of D. M. Wertz in 1912 and was very abundant there and in adjacent orchards during the following year. It was also taken in considerable numbers during 1913 at the Newcomer orchard near Midvale, Pa. This ladybird worked so effectively at Mont Alto, Pa., as nearly to exterminate a very severe infestation. *H. binotata* (fig. 17) differs somewhat from the common species of ladybirds, both in its habits and life history. The adult beetles hibernate under bark and in rubbish and become active in early spring. They feed upon

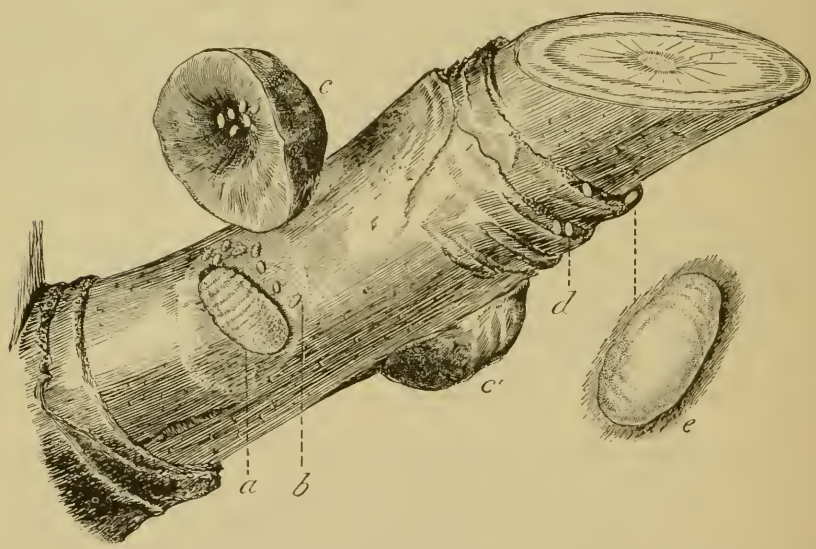


FIG. 18.—Eggs and a second-instar larva of *Hyperaspis binotata* as it appears under a displaced scale: *a*, Second instar as disclosed by displacing the host; *b*, larvæ of the terrapin scale; *c*, a displaced scale; *d*, eggs of the predatory beetle *Hyperaspis binotata* in situ; *e*, egg, highly magnified. All much enlarged. (Original.)

honeydew and upon aphides during the early part of the season but are unable to attack the lecanium in the spring because of its hard derm. They feed upon it readily when the derm is crushed.

The eggs, which are a salmon color, are deposited singly upon the twigs, a favorite place being upon the ringlike scars that mark the limit of the seasonal growth. (Fig. 18, *d*, *e*.) The eggs are too small to be seen readily by the unaided eye. They commence to hatch about the middle of May and the young seek the mature scales and enter their brood chambers by way of the anal cleft. When once within the brood chambers they prey upon the newborn young. The ladybird larvæ make their first molt within this brood chamber and continue to feed until the end of the second instar; by this time the Hyperaspis larvæ are so large that they crowd the brood chamber and often displace their host. Finally the larvæ leave the host and make the second molt, usually at the base of a fruit spur, and then attack other scales, which they do by forcing their heads under the margin and displacing them. In this manner they continue through the third and fourth instars, each larva destroying many gravid scales. When all the gravid females are destroyed the Hyperaspis larvæ, which are then mostly in the fourth instar (fig. 19), migrate to the leaves and continue their feeding upon such of the larvæ as have reached the leaves. Afterwards the ladybird passes the pupal stage in a pupa case attached to the leaves or to the twigs, and sometimes in cavities under the bark. Most of the hibernating beetles die before the first brood emerges from the pupa.

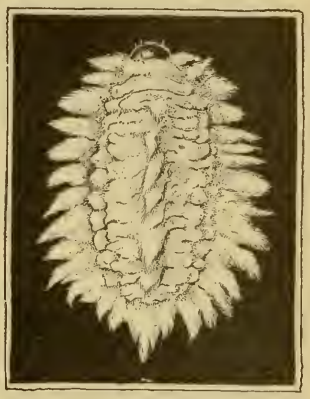


FIG. 19.—The fourth-instar larva of *Hyperaspis binotata* as it appears when attacking the larvæ of the terrapin scale. Much enlarged. (Original.)

PARASITES.

The terrapin scale is heavily parasitized, and this parasitism is mostly confined to the female, though the male is slightly attacked. The first and second instars are very free from parasites, but a heavy attack starts soon after the young females have attached to the twigs. This attack increases in violence until checked by the approach of winter. Most of the parasites pass the winter within the host and emerge early in the season to make a new attack, which reaches its maximum just before the scales begin producing young.

Coccophagus lecanii Fitch was the most abundant species reared in 1912, but *C. cognatus* Howard was also abundant, especially in the fall. In 1913 *C. lecanii* Fitch was rare. In its place *C. cognatus*

appeared in large numbers and attacked the developing females in the spring. That which was apparently the first brood emerged from the hosts about June 30. This infestation was very noticeable owing to the excessive blackening of the scales, as from 20 to 50 per cent of the scales were killed. Later this same species made an attack upon the male larvæ when in the second instar, and in some instances 5 per cent of the males were destroyed. At Ledy Station, Pa., and at Midvale, Pa., this species made a heavy attack in the fall, but at Mont Alto, Pa., it was scarce, owing to the almost complete destruction of the host by *Hyperaspis binotata*.

Aphycus stomachosus Gir. was the most abundant parasite in 1913, being more numerous than *C. cognatus*. It was reared in greatest numbers from the nearly mature females in the early part of June, but it was also taken in large numbers in the orchards during the first half of September. *Aphycus johnsonii* Howard was reared in small numbers from both *Eulecanum nigrofasciatum* Pergande and *E. corni* Bouché at Mont Alto, Pa., but the last-named species seemed to prefer *L. corni* as a host.

Besides the foregoing parasites, *Blastothrix sericae* Dalman was reared from *E. nigrofasciatum* in 1912, as well as numerous specimens of a new genus of Encyrtidæ.

A number of specimens of *Prospalta* sp. were taken from the parasite cages during the season of 1912, but these may have come from armored scales that were introduced by accident.

The records of this bureau contain references to the following species as parasites of *Eulecanium nigrofasciatum*:

Coccophagus ater How.
cognatus How.
lecanii Fitch.
cinguliventris Gir.
longifasciatus How.
flavoscutellum Ashm.
fraternus How.
Aphycus annulipes Ashm.
johnsoni How.
stomachosus Gir.
Anagyrus nubilipennis Gir.
Eunotus lividus Ashm.
Pachyneuron altiscuta How. (secondary).
Prospalta aurantii How.
Chiloneurus albicornis How.
Blastothrix sericea Dalm.
Comys fusca How.

SOOTY MOLDS.

Eulecanium nigrofasciatum does most of its damage to the peach through its mold-infested honeydew, which is deposited in varying amounts throughout the entire season. While this honeydew is objectionable, it would cause very little damage were it not for the sooty molds which grow abundantly on the leaves, twigs, and fruit and on the soil beneath the trees when these are coated with the honeydew. This honeydew becomes noticeable only at three times during the year. A slight deposit from the maturing females appears in

April and May, and another in July from the leaf-attached larvæ; but neither of these deposits is sufficient to do much damage. The really important deposit starts about August 10, at the time when the females attach to the twigs, and continues until the approach of cold weather. The amount of sooty mold produced is limited apparently only by the amount of honeydew excreted. The mold becomes noticeable during the first week in July as black streaks which first appear in the depressions on the upper surface of the leaves. It gradually increases in amount until the middle of August, and from this time until the middle of September the increase is very rapid. The infestation is at its worst about the middle of September, at which time fruit, foliage, and branches are covered with a sticky black slime. The extent of the injury depends upon the degree of infestation and upon the time of ripening of the fruit. Late varieties are damaged most by the mold-infested honeydew, as it shows worse upon fruit which ripens after the middle of August.

REMEDIAL MEASURES.

At the beginning of this investigation lime-sulphur was known to be ineffective and kerosene emulsion was considered unsatisfactory in the control of the terrapin scale. The so-called miscible oils (proprietary emulsifiable oils), however, were believed to be reasonably efficient when properly employed, though it was believed that there was more or less danger to the trees and fruit buds from their use.

For convenience in treatment the materials used in these experiments are considered in groups. In all 62 experiments were performed, most of them in the orchard of D. M. Wertz, at Mont Alto, Pa. The others were at Midvale, Pa., and at Washington, D. C.

A consideration of the life history of this scale shows that it can be attacked both in the larval and the adult stages. The adult stage, owing to its long duration and accessibility, obviously offers the more favorable opportunity for treatment. During the first season sprayings were made against both the larva and the adult.

OIL SPRAYS.

Experience shows that all oil sprays are most effective when applied as a fine mist and under strong pressure. All oils were applied with disk nozzles of the Vermorel type, having apertures of one-sixteenth inch. The oils noted in Table XXXVIII, all of which were applied in the spring after the buds had started to swell but before they had opened, proved to be inefficient. These oils were emulsified as follows:

Oil	2 gallons.
Soap (hard)	½ pound.
Hot water	1 gallon.

The soap was dissolved in the water and to this the oil was added. The whole was churned through a spray pump until no free oil remained. The emulsion was then diluted to the required strength and applied.

Figure 20 shows that portion of the Wertz orchard in which most of the experimental work was done. The orchard is in apples, interplanted mostly with Smock and Chair's Choice peaches. The trees were 11 years old in 1912 and very vigorous. At the beginning of the investigation these trees were grouped into 14 major plats, as shown in the figure. The check plats were used as such until a better method of checking was devised, when they were subplatted and sprayed. Most of the checking was done by scale counts from tagged branches upon special check trees left within the plats.

The rosin-oil emulsion was very efficient so far as killing scales was concerned. This oil dried rapidly, the trees soon appeared as if covered by a varnish, and the scales died almost at once. Unfortunately this oil gave very severe spray injury and some of the trees were so severely damaged that they required drastic pruning and stimulation to save them. While the spray injury could have been lowered by reducing the amount of oil, it was not thought advisable to continue the experiments.

The corn oil, which was also used as a 20 per cent emulsion, was equally good as a scale killer but formed a waxy scum over the branches and penetrated deeply into the tree, causing the death of many large limbs. These trees required drastic pruning and stimulation, but the injury was not so severe as in the case of the rosin oil. It was, however, too severe to justify its further use.

The gasoline, which was used as a 10 per cent emulsion, had a very low efficiency as a scale treatment but gave promise in other ways, as it readily dissolved the wax film which protects the scale from water, and it caused the scales to loosen temporarily from the bark. After the emulsion evaporated, however, the scales soon resumed their normal condition. This emulsion produced no spray injury.

MISCIBLE OILS (PROPRIETARY EMULSIFIABLE OILS).

In order to secure data for the better understanding of the factors that enter into the successful use of miscible oils the sprayings enumerated in Table XXXIX were made.

FIG. 20.—Map of the experimental plats in the D. M. Wertz orchard, Mont Alto, Pa. (Original.)
A, Apple trees.
o, Peach trees.

TABLE XXXVIII.—*Data from plats sprayed with rosin-oil, corn-oil, and gasoline emulsions for the terrapin scale.*

Plat.	Experiment No.	Number of trees.	Age.	Degree of infestation.	Formula.	Application.	Scale count.					Spray injury.
							Date.	Total.	Dead.	Living.	Per cent dead.	
			Years.									
VII D	1	11	11	Heavy	Rosin oil, 20 per cent emulsion.	Apr. 11, 1912, dormant.	Apr. 15, 1912	100	98	2	98	Very severe.
							May 2, 1912	100	98	2	98	Do.
VII C	2	11	11	...do....	Corn oil, 20 per cent emulsion.	.....do.....	Apr. 20, 1912	100	98	2	98	Slight.
							Apr. 18, 1912	800	800	0	100	Do.
							May 5, 1912	100	98	2	98	Very severe.
Washington, D. C.	3	1	2	...do....	Gasoline, 10 per cent emulsion.	Mar. 12, 1913, dormant.	Mar. 20, 1913	100	10	90	10	None.

TABLE XXXIX.—*Data from plats sprayed with miscible oils for the terrapin scale, seasons of 1912 and 1913.*

Plat.	Experiment.	Number of trees.	Age.	Degree of infestation.	Formula.	Application.	Scale count.					Spray injury.	Per cent dead in checks.	Final result.
							Date.	Total.	Dead.	Living.	Per cent parasitized.	Per cent dead.			
1912.			*Yrs.*											
North plat	1	40	11	Heavy	Miscible oil, 1 part; water, 18 parts.	Apr. 11, 1912	Apr. 15, 1912	200	180	20	0	90	None	0	Efficient.
South check, *d*	2	16	11	do	do	Dec. 23, 1912	Mar. 18, 1914	100	85	15	0	85	Injury severe.	0	Inefficient.
XI	3	100	12	Moderate	do	Mar. 29, 1913	Apr. 23, 1914	1,081	848	233	0	78.45	None	0	Do.
							May 2, 1914	1,725	1,062	663	0	61.57	do	0	
III *a*	4	17	11	Heavy	Miscible oil, 1 part; water, 16 parts.	Dec. 23, 1912	Mar. 18, 1914	100	85	15	0	85	Injury severe.	0	Do.
South check, *c*	5	28	11	do	Miscible oil, 1 part; water, 20 parts.	do	Mar. 18, 1913	100	70	30	0	70	Severe	0	Do.
South check, *b*	6	30	11	do	Miscible oil, 1 part; water, 24 parts.	do	do	246	133	113	0	46	Slight	0	Do.
South check, *a*	7	16	11	do	Miscible oil, 1 part; water, 30 parts.	do	do	100	15	85	0	15	do	0	Do.
1913.															
X *f*	8	17	12	do	Miscible oil, 1 part; water, 16 parts.	Mar. 29, 1913	Apr. 22, 1913	951	769	182	0	80.90	Very slight	10	Efficient.
							May 2, 1913	1,072	981	91	0	91.52	trace.		
X *c*, *d*, *e*	9	55	12	do	Miscible oil, 1 part; water, 20 parts.	Mar. 28, 1913	Apr. 25, 1913	292	265	27	0	90.76	None	10	Do.
							May 19, 1913	1,033	928	105	0	89.84	do		
X *c*, *d*, and X *a*	[1] 10	75	12	do	Miscible oil, 1 part; gasoline, 1 part; water, 18 parts.	do	May 20, 1913	2,419	1,875	544	10	77.57	do	10	Do.
IX *a*, *b*, and X *d*	[1] 11	65	12	do	Miscible oil, 1 part; gasoline, 1 part; water, 20 parts.	do	May 21, 1913	2,432	1,967	465	10	80.28	do	10	Do.
VII *d* and VIII *b*	[1] 12	60	12	do	Miscible oil, 1 part; gasoline, 1 part; water, 28 parts.	do	do	1,120	936	184	10	83.57	do	10	Do.
VII *a*, *c*	13	45	12	do	Miscible oil, 1 part; gasoline, 1 part; water, 38 parts.	do	May 9, 1913	685	139	546	10	20.30	do	10	Inefficient.
Midvale, Pa	[1] 14	200	12	do	Miscible oil, 5 parts; gasoline, 3 parts; water, 92 parts.	Nov. 6, 1913	Mar. 31, 1914	1,784	1,142	642	0	64.01	Trace	55.01	Moderately efficient.

[1] The apparent discrepancy between the per cent dead and the final estimate is due to the falling of dead scales in the interval between spraying and counting.

In all cases the plats were first carefully inspected and typical branches were marked with tags which stated the condition of the scales and the nature of the infestation. About 10 per cent of the tagged trees were then left unsprayed and the results were taken by an individual examination of the scales upon the tagged branches. Before taking the scale count all winter killed and parasitized scales were removed from the branches, so that the count includes only scales that were alive and normal at the time the sprayings were made. The result of miscible-oil sprays became evident in a very few days after the application, when the dead scales began to drop. Because of the dropping of the scales it was found that counts should be made within one week after the application to show the true mortality. The result of delaying the count is well illustrated by a comparison of experiments 1 and 2. So far as the counts show these applications were equally effective, but in the second experiment there was an interval between the application and the count, and some of the dead scales had disappeared, thus making the mortality appear lower than it was. In comparing experiments 1 and 2, it appears that miscible oil at the strength of 1 gallon of oil to 18 gallons of water, when applied in the spring, is moderately effective against the scale, without producing injury to the trees, and that when applied in the fall it is nearly as effective against the scale, but produces severe injury to the trees.

Experiment 3 was made to determine the effect of using the regular lime-sulphur nozzles in applying miscible oil, and the plat was sprayed by the regular orchard force without oversight. Of the two counts made in experiment 3, the first represents the true mortality and the second shows only the condition of the scales present on May 2, when there were fewer dead scales than on April 23, due to their falling in the interval between the counts. The results in experiments 1 and 3 show clearly the necessity for using nozzles with smaller apertures and for making a more thorough application than is customary when applying dormant lime-sulphur sprays.

Experiments 4, 5, 6, and 7 show the effects of applying miscible oil in the winter, at a time when both the lecanium and the trees are dormant. When these applications were made the day was mild and calm, with the temperature well above freezing. A power outfit was used and the trees were sprayed until there was a slight dripping from the branches. The time between the date of applying these sprays and the date of making the scale count was rather too long to give the full mortality. The error, however, was small and was estimated at less than 5 per cent. These four experiments were all ineffective. Experiment 4 was accompanied by severe injury and experiments 5, 6, and 7 showed spray injury and failed to control the scale. It is therefore concluded that miscible oils are

not satisfactory when applied against the terrapin scale in the winter season.

In the spring of 1913 6 sprayings were made to test the efficiency of commercial miscible oils to which a wax solvent had been added. Accordingly experiments 8, 9, 10, 11, 12, and 13 were made and the sprays were applied in connection with the sprayings in experiments 1 to 7. It is to be noted that the spray used in experiment 8 was quite effective as a scale destroyer and that only a small amount of spray injury resulted. It serves, by contrast with experiment 4, to show that oils which are dangerous and ineffective when applied in winter may be applied with success in the spring. Particular attention is called to the effective work done by miscible oil when used at the rate of 1 gallon to 20 gallons of water in experiment 9. Where gasoline was added to the miscible oil there was a decided loosening of the scales, and many of the dead scales fell before the count was made, while comparatively few fell where miscible oil was used alone. This condition was noticed at the completion of the count, and comparisons were then made of the number of living scales in the plats having miscible oil only, in contrast with those having both miscible oil and gasoline, with the result that in all cases fewer living scales were found upon the twigs treated with the spray containing gasoline than upon those having miscible oil alone. It is therefore concluded, regardless of the count, that miscible oils are improved as a spray by the addition of gasoline emulsion.

Experiment 14 was made in Mr. A. Newcomer's orchard near Midvale, Pa., November 6, 1913, to determine the effect of a miscible oil and gasoline mixture when applied in the fall just after the leaves had fallen, and 15 trees were sprayed for comparison with the same percentage of miscible oil, but without gasoline. Unfortunately it was not possible to make a scale count until March 31, 1914, when many of the dead scales had fallen. Infested limbs upon the check trees were compared with similar branches on the trees in experiment 14, and these comparisons showed that the formula was more effective with gasoline than without it. The spray injury in this experiment was slight and the treatment was moderately efficient. All of the experiments made March 28 and 29, 1913, were finally rated as efficient, except No. 13, where the spray was deficient in oil. It is the author's belief that miscible oil—while not as desirable as linseed-oil emulsion, which is treated later—can be used with safety when applied just before the buds open, in dilutions of 1 gallon in 16 to 20 gallons of water. It is very effective, especially when the oil is mixed with one-half its volume of gasoline (emulsified). The natural mortality in the Newcomer orchard for the winter of 1913–14, as determined by a scale count from unsprayed trees, was 55.01 per cent.

COTTONSEED OIL.

The 10 experiments summarized in Table XL were made with cottonseed oil during 1912 and 1913. This oil was emulsified in all cases exactly as kerosene oil is emulsified in the preparation of kerosene emulsion. The sprays were applied in experiments 3, 4, 5, 6, and 7 with a hand sprayer and the applications were so thoroughly made that every scale was covered. The sprays in the other experiments were applied with a power sprayer.

TABLE XL.—*Experiments with cottonseed-oil emulsions against the terrapin scale.*

Plat.	Experiment No.	Trees.	Age.	Degree of infestation.	Formula.	Application.	Spray injury.	Final result.	Scale count.						Per cent dead in check.
									Date.	Total.	Dead.	Living.	Per cent parasitized.	Per cent dead.	
			Yrs.												
VIII *a*, east end.	1	11	11	Very heavy	Cottonseed oil, 20 per cent.	Apr. 11, 1912, dormant.	Slight..... Severe.....	Inefficient.....	Apr. 18, 1912 Apr. 20, 1912	800 200	800 188	0 12	0 0	100 94	0 0
I *d*, east end..	2	7	11	...do.....	Cottonseed oil, 18 per cent.	Nov. 9, 1912, dormant.	....do..... ....do.....	....do.....	Dec. 22, 1912 June 10, 1913	100 100	100 100	0 0	0 0	100 100	0 0
A, Washington, D. C.[1]	3	1	2	Heavy....	Cottonseed oil, 10 per cent.	Jan. 23, 1913, dormant.	Very severe.	.....do.....	Feb. 7, 1913	300	300	0	0	100	0
B, Washington, D. C.	4	1	2	...do.....	Cottonseed oil, 5 per cent.	Jan. 30, 1913, dormant.	None..... ....do.....	Very efficient.	Feb. 8, 1913 Apr. 24, 1913	200 200	190 190	10 10	0 0	95 95	0 0
C, Washington, D. C.	5	2	2	...do.....	Cottonseed oil, 2.5 per cent; gasoline, 2.5 per cent; water, 95 per cent.	Mar. 15, 1913, dormant.	....do..... ....do.....	....do.....	Mar. 20, 1913 Mar. 24, 1913	100 100	95 98	5 2	0 0	95 98	0 0
D, Washington, D. C.	6	1	2	...do.....	Cottonseed oil, 1.5 per cent; gasoline, 3.5 per cent; water, 95 per cent.	Mar. 15, 1913, dormant.	.....do.....	Inefficient.....	Apr. 24, 1913	100	40	60	0	40	0
E, Washington, D. C.	7	1	2	...do.....	Cottonseed oil, 10 per cent; gasoline, 5 per cent; water, 85 per cent.	Mar. 19, 1913, dormant.	Severe.....	.....do.....	.....do.....	218	215	3	0	98.63	0
VI, *a*, *b*, *c*[2]....	8	28	12	...do.....	Cottonseed oil, 2.5 per cent; gasoline, 2.5 per cent; water, 95 per cent.	Mar. 29, 1913, dormant.	None.....	Efficient.....	May 26, 1913	1,849	1,682	167	0	90.97	0
VI, *d*[2].....	9	16	12	...do.....	Cottonseed oil, 5 per cent.	Mar. 28, 1913, dormant.	....do..... Very slight..	Inefficient.....	Apr. 25, 1913 May 24, 1913	1,015 1,526	512 615	503 875	0 0	50.44 42.46	0 0
Midvale, Pa.[2].	10	90	12	...do.....	Cottonseed oil, 5 per cent; gasoline, 3 per cent; water, 92 per cent.	Nov. 5, 1913, dormant.	None..... ....do.....	Efficient.....	Dec. 4, 1913 Mar. 31, 1914	100 100	85 90	15 10	0 0	85 90	21

[1] This tree died from spray injury. [2] These counts represent less than the maximum efficiency of the spray, owing to the dropping of killed scales before the date of counting.

TABLE XLI.—*Experiments with raw linseed-oil emulsions against the terrapin scale.*

Plat.	Experiment No.	Number of trees.	Age.	Degree of infestation.	Formula.	Application.	Scale count.						Spray injury.	Final result.
							Date.	Total.	Dead.	Living.	Parasitized.	Per cent dead.	Per cent dead in check	
			Yrs.											
VIII *b*.....	1	11	11	Heavy....	Linseed oil, 20 per cent emulsion.	Apr. 5, 1912, dormant.	Apr. 20, 1912	123	115	8	0	93.49	0	Moderately severe.
							June 28, 1912	100	98	2	0	98	0	Severe..
							July 17, 1912	100	98	2	0	98	0	Inefficient.
Washington, D. C.	2	1	2	....do.....	Linseed oil, 10 per cent emulsion.	Mar. 19, 1913, dormant.	Mar. 24, 1913	100	100	0	0	100	0	None.... Very efficient.
V *d*.....	3	11	12	....do.....	Linseed oil, 5 per cent emulsion.	Mar. 28, 1913, dormant.	Apr. 25, 1913	722	601	121	0	83.24	0	...do..... Moderately efficient.
V *b, c*.....	4	22	12	....do.....	Linseed oil, 2.5 per cent; gasoline, 2.5 per cent.	Mar. 28, 1913, dormant.	May 28, 1913	889	728	161	0	81.89	0	...do..... Efficient.
Midvale, Pa..	5	200	12	....do.	Linseed oil, 5 per cent; gasoline, 3 per cent.	Nov. 5, 1913	Mar. 30, 1914	1,489	1,489	0	0	100	54.74	...do..... Very efficient.

TABLE XLII.—*Data from plats sprayed with mixed oils for the terrapin scale.*

Plat.	Experiment No.	Trees.	Age.	Degree of infestation.	Formula.	Application.	Scale count.							Spray injury.	Final results.
							Date.	Total.	Dead.	Living.	Per cent parasitized.	Per cent dead.	Per cent dead in check.		
			Yrs.												
III *d*.....	1	22	12	Heavy....	Raw linseed oil 2½ parts, cottonseed oil 2½ parts, water 95 parts.	Mar. 28, 1913	May 29	1,840	1,334	506	0	72.83	0	None....	Inefficient.
IV *a*.....	2	11	12	.....do.....	Raw linseed oil 1½ parts, cottonseed oil 1½ parts, gasoline 2½ parts, water 95 parts.	.....do.....	May 28	1,639	874	765	0	53.33	0	...do.....	Do.

TABLE XLIII.—*Experiments against the terrapin scale with sprays containing nicotine as the active ingredient, Mont Alto, Pa.*

Plat.	Experiment No.	Trees.	Age.	Degree of infestation.	Formula.	Application.	Scale count.								Final results.
							Date.	Total.	Dead.	Living.	Per cent parasitized.	Per cent dead.	Per cent dead in check.	Spray injury.	
IV	1	73	*Yrs.* 11	Heavy	Nicotine sulphate 1 part, 3 per cent kerosene emulsion 400 parts.	Apr. 5, 1912, dormant.	Apr. 20	175	25	150	0	14.3	0	None	Inefficient.
VI	2	93	11	do	Nicotine sulphate 1 part, 10 per cent lime-sulphur solution 400 parts.	do	do	186	24	132	0	13	0	do	Do.
VII	3	88	11	do	Nicotine sulphate 1 part, 1.6 per cent miscible-oil emulsion 400 parts.	do	do	100	30	70	0	30	0	do	Do.
V	4	90	11	do	Tobacco extract 1 part, 3 per cent kerosene emulsion 20 parts.	do	May 24	200	23	177	0	11.5	0	do	Do.
North check	5	34	11	do	Nicotine sulphate 1 part, 3 per cent kerosene emulsion 400 parts.	Aug. 6, 1912, twigward migration.	Aug. 16	300	55	245	0	18.3	0	do	Do.
II *c, d*	6	40	11	do	Nicotine sulphate 1 part, 3 per cent kerosene emulsion 400 parts.	Aug. 22, 1912, young females upon the twigs.	Sept. 16	100	50	50	0	50	0	Severe	Do.
II *a*	7	12	11	do	Tobacco extract 1 part, 3 per cent miscible-oil emulsion 20 parts.	do	Sept. 13	100	60	40	0	60	0	do	Do.
I *a, b, c*	8	40	11	do	Nicotine sulphate 1 part, 6 per cent kerosene emulsion 400 parts.	Nov. 9, 1912, dormant.	Dec. 22	100	8	82	0	8	0	None	Do.

TABLE XLIV.—*Coating sprays against the terrapin scale applied in 1912.*

Plat.	Experiment No.	Trees.	Age.	Degree of infestation.	Formula.	Application.	Scale count.					Per cent dead in check.	Spray injury.	Final results.
							Date.	Total.	Dead.	Living.	Per cent parasitized.	Per cent dead.			
			Yrs.											
V	1	90	11	Heavy	Self-boiled lime sulphur, 8–8–50.	May 24, 1912 (scales mature).	Sept. 3	200	23	177	10	11.5	10	None	Inefficient.
IX	2	77	11	...do	...do	June 17, 1912 (leafward migration).	July 8	100	15	85	0	15	0	...do	Do.
X	3	105	11	...do	...do	June 17, 1912	July 8	100	0	100	0	0	0	...do	Do.
						July 9, 1912	Sept. 13	800	761	39	0	96.3	90	...do	Do.
XI	4	77	11	...do	...do	June 17, 1912	July 8	100	.....	100	0	0	0	...do	Do.
						July 8, 1912									
VII *d*	5	24	11	...do	Self-boiled lime sulphur 8–8–50, and 2½ gallons of tobacco extract.	Aug. 6, 1912	Sept. 5	100	90	10	0	90	90	None	Do.
						July 9, 1912 (leaf-attached larvæ.	...do	100	90	10	15	90	90	...do	Do.
VII *d*	6	10	11	...do	Self-boiled lime sulphur 8–8–50, plus 1 gallon tobacco extract.	July 9, 1912	...do	100	90	10	15	90	90	...do	Do.
South check *a*	7	21	11	...do	Stone lime 12 pounds, sulphur 5 pounds, water 50 gallons.	Aug. 6, 1912 (twigward migration).	Aug. 16	100	25	75	10	25	10	...do	Do.
III *b*, west end	8	12	11	...do	Paris white 15 pounds, glucose 3 gallons, water 47 gallons.	Aug. 5, 1912	Sept. 30	100	10	90	10	10	10	...do	Do.
III *a*, west end	9	12	11	...do	Stone lime 20 pounds, casein 5 pounds, water 50 gallons.	Aug. 6, 1912	...do	200	22	178	10	11	10	...do	Do.
III *a*, east end	10	7	11	...do	Pulverized China clay 15 pounds, water 50 gallons.	...do	...do	100	10	90	10	10	10	...do	Do.

TABLE XLV.—*Experiments against the terrapin scale with coating sprays to which flour had been added, season of 1913.*

Experiment No.	Trees.	Age.	Degree of infestation.	Formula.	Application.	Scale count.						Per cent dead in check.	Spray injury.	Final results.
						Date.	Total.	Dead.	Living.	Per cent parasitized.	Per cent dead.			
		Years.												
1	12	12	Heavy	Flour 10 pounds, stone lime 15 pounds, sulphur 20 pounds, water 50 gallons.	June 12, 1913	July 8	1,007	948	59	5	94.1	21	None	Very efficient.
2	12	12	...do	...do	June 12, 1913	July 7	1,152	1,141	11	5	99	21	...do	Do.
					July 10, 1913	Aug. 4	100	99	1	5	99	21	...do	
3	12	12	...do	...do	July 10, 1913	Oct. 14	100	26	74	5	26	21	...do	Inefficient.
4	3	12	...do	...do	July 29, 1913	Aug. 6	100	15	85	0	15	0	...do	Do.
5	8	12	...do	Flour 10 pounds, stone lime 15 pounds, sulphur 20 pounds nicotine sulphate 1 pint, water 50 gallons.	June 17, 1913	June 28	2,306	2,093	23	5	90.71	21	...do	Efficient.
6	16	12	...do	...do	June 17, 1913 July 10, 1913	Aug. 8	100	90	10	5	90	21	...do	Do.
7	6	12	...do	...do	July 10, 1913	...do	100	26	74	5	26	21	...do	Inefficient.
8	1	12	...do	...do	July 29, 1913	Aug 6 Aug. 9	100	26	74	5	26	21	...do	Do.
9	5	12	...do	Flour 10 pounds, water 50 gallons.	July 10, 1913	Aug. 8	100	0	100	0	0	0	...do	Do.
10	5	12	...do	Flour 10 pounds, stone lime 15 pounds, sulphur 20 pounds, water 50 gallons.	July 10, 1913, twigward migration.	...do	100	0	100	0	0	0	...do	Do.

The spray used in experiment 1, which was made just before the flower buds burst, was very effective as an insecticide. Every scale that was covered with the spray solution was killed. Of 1,000 scales examined only 1.2 per cent were alive, and these were protected in various ways from the spray and were not completely drenched. The spray injury was severe, however, owing to the excessive amount of oil.

Experiment 2 was made late in the fall with 2 per cent less oil. This spray was very efficient against the scale, but the injury was more pronounced than in experiment 1. The trees used in both experiments required severe pruning and a liberal application of sodium nitrate to restore them to their original vigor.

Experiment 3 was made at Washington, D. C., to determine the effect of this oil upon young trees. A vigorous 2-year-old tree was thoroughly sprayed with a hand sprayer until all the scales were wet with a 10 per cent emulsion of the oil. All the scales upon this tree were destroyed, but the spray injury was so severe that the tree died. It is worthy of note that this was the only tree killed with oil during the two seasons' work. The increased tolerance of the older trees to oil seems to be due entirely to the protection afforded by their corky bark.

Experiment 4 was also made at Washington. It shows that cottonseed oil in a 5 per cent emulsion can be applied effectively and safely to 2-year-old trees in mild winter weather. This formula, however, does not contain enough of oil to make it effective against the terrapin scale when applied on old trees, as is clearly shown in experiment 9.

Experiment 5 was also made at Washington, D. C. Two heavily infested 2-year-old trees were sprayed with a 5 per cent emulsion of equal parts of cottonseed oil and gasoline. A hand sprayer was used and all the scales were thoroughly wetted with the spray. Nine days after the application 98 per cent of the scales were dead and no spray injury developed during the season. This spray was also effective against scale upon old peach trees, as is shown in experiment 8.

In experiment 6 the amount of oil was reduced to 1.5 per cent and the gasoline was increased to 3.5 per cent. The application was made in the same manner and at the same time as in experiments 3, 4, and 5, but it was ineffective, owing to the small percentage of oil. The high percentage of gasoline increased the wax-solvent power of the solution and its narcotic power, but did not directly contribute to its killing power.

Experiment 7, in which 10 per cent cottonseed oil and 5 per cent gasoline was used, gave practically the same results as 10 per cent cottonseed oil when used alone. Since experiment 7 shows less

spray injury than experiment 3, it is evident that the gasoline did not tend to increase the spray injury. This experiment, in connection with experiment 3, shows that a 10 per cent emulsion of the oil, even when used at the most favorable season, is too strong for 2-year-old trees whether used with or without gasoline. The formula in experiment 7, while containing more oil than is required for killing scale upon young trees, would undoubtedly be very effective when used upon old trees, but owing to the effective results obtained with 2½ per cent of this oil in experiments 5 and 8, it was not thought advisable to experiment further with the 10 per cent emulsion.

In experiment 8 an emulsion containing 2½ per cent of cottonseed oil and 2½ per cent of gasoline was applied to 28 vigorous 12-year-old trees at Mont Alto, March 29, 1913, with very satisfactory results. The interval between the application of this spray and the time of making the scale count was too long to show the maximum efficiency of the spray, nevertheless the mortality as shown is above 90 per cent and there was no spray injury. Observations made upon the trees used in this experiment show that the oil content could have been considerably increased without injury to the trees.

Experiment 9, in which a 5 per cent emulsion of cottonseed oil was carefully sprayed upon 16 trees at Mont Alto, Pa., gave unsatisfactory results. The mortality was about 50 per cent and the spray injury was negligible. The oil in this case seemed to lack penetration and spreading power.

A comparison of the data in this experiment with that in experiments 5, 8, and 10 shows that a 5 per cent emulsion of this oil is satisfactory only when used with gasoline. Experiment 10 was the last one performed with cottonseed oil. An extensive spraying was made to test the efficiency of the gasoline and cottonseed-oil emulsion when applied in the fall. This experiment was successful and showed that the terrapin scale can be attacked in the fall with satisfactory results. Cottonseed oil, however, gives its best results when applied in the spring. It is possible to increase the percentage of cottonseed oil in this formula up to as high as 7 per cent without noticeable injury to the trees. This increase in oil, however, adds to the cost of the spray without greatly increasing its efficiency, except for use on old trees with very rough bark. In this case it may be found of advantage to use 7 per cent of the oil.

LINSEED OIL.

Five experiments against the terrapin scale were made with raw linseed oil. The essential facts established in these experiments are shown in Table XLI.

Experiment 1 was made at Mont Alto, Pa., upon vigorous 11-year-old trees that were nearly ready to burst into bloom. The same

power outfit was used as in applying the cottonseed-oil sprays. The oil was emulsified in the same way as kerosene in making kerosene emulsion. This oil at 20 per cent gave an efficiency of from 93 to 100 per cent, but the injury to the trees was severe. It did far less injury, however, than any other of the oils used at this strength. This experiment shows that raw linseed oil was a promising oil and that it should be used at a much decreased strength.

Experiment 2 was performed on March 19, 1913, by spraying a vigorous 2-year-old tree at Washington, D. C., with a 10 per cent emulsion of raw linseed oil. This spray was applied very thoroughly with a hand sprayer at the time the buds were swelling. Every scale upon this tree was killed and there was no spray injury. The experiment shows that it is feasible to apply a 10 per cent emulsion to 2-year-old trees in the spring without injury.

Experiment 3 demonstrated that a 5 per cent emulsion of raw linseed oil will destroy more than 80 per cent of the scales upon 12-year-old trees, provided the application is made in the spring before the buds open. In experiment 4 the formula used differs from the one used in No. 3 in that gasoline was substituted for one-half of the oil. The scale count gives nearly the same efficiency for this experiment as for the preceding one. This experiment shows clearly that gasoline increases the efficiency of the spray. Experiment 5 was made by spraying 200 moderately vigorous 12-year-old peach trees at Midvale, Pa., November 5, 1913, at which date the trees had just finished shedding their leaves. An emulsion containing 5 per cent raw linseed oil and 3 per cent gasoline was applied with a power sprayer, furnishing 175 to 200 pounds pressure, and equipped with angle nozzles having apertures of one-sixteenth inch. The efficiency upon well-sprayed branches was 100 per cent and there was no spray injury.

Experiments 4 and 5 show that an emulsion containing 5 per cent raw linseed oil and 3 per cent gasoline will effectively control the terrapin scale without injury to the trees. While experiment 5 shows that linseed oil gives good results in the fall, the author recommends that this oil be applied in the spring just before the buds open.

Cost of Linseed Oil.

At the date of writing this paragraph linseed oil sold in Washington, D. C., for 50 cents per gallon in barrel lots, and gasoline at 13 cents per gallon. The cost of this spray, exclusive of the labor of making it, would be about 3 cents per gallon.

5 gallons raw linseed oil, at 50 cents	$2.50
3 gallons gasoline, at 13 cents	.39
2 pounds laundry soap, at 5 cents	.10
92 gallons water	
100 gallons	2.99

It requires from 1½ to 2½ gallons of this emulsion thoroughly to spray a vigorous 12-year-old tree. The average tree of this age requires about 2 gallons, while a 2-year-old tree requires from a pint to a quart. It appears that from these figures the spray material will cost from 1 cent to 8 cents per tree.

A single application of this spray, if carefully made, will control the terrapin scale. It has been found that the best way of preparing this spray is by mixing 5 gallons of raw linseed oil and 3 gallons of gasoline and then adding 2 pounds of soap dissolved in 4 gallons of hot water. The whole is churned for 5 minutes through a spray pump, then diluted to double its volume and churned again for 1 minute, after which it should be diluted to 100 gallons, when it is ready to use.

MIXED OILS.

Two experiments were performed in 1913 with emulsions of mixed oils. These emulsions were made and applied in exactly the same way as the linseed-oil emulsions.

Table XLII shows the chief details, and the results for the mixed-oil emulsions. These experiments, when compared with experiments 3 and 4 of Table XLI, show that these mixed oils were less efficient than raw linseed oil and that there is no advantage in mixing them.

NICOTINE.

Eight experiments were made with nicotine compounds. These sprays were applied partly with a barrel sprayer and partly with a power sprayer, but the same set of disk nozzles was used in all cases. The chief details and the results of these experiments are recorded in Table XLIII.

When reference is made to nicotine sulphate, the commercial article containing 40 per cent of nicotine is intended; likewise references to tobacco extract refer to preparations containing 2.7 per cent of nicotine, or its equivalent.

Experiments 5 and 6 of Table XLIV and experiments 5, 6, 7, and 8 of Table XLV are to be considered in connection with Table XLIII. Of these 14 experiments, 5 were directed against the hibernating scales (4 of these in the spring and 1 in the fall); 5 against the leaf-attached larvæ, 2 against the females while making the twigward migration, and 2 against the young females while making their maximum growth. These experiments were all negative and showed that nicotine is ineffective against the terrapin scale.

COATING SPRAYS.

A number of experiments were performed in 1912 with coating sprays, to determine the feasibility of smothering the scale. The chief details and the results of these experiments are recorded in

Table XLIV. The first 4 experiments were made with self-boiled lime-sulphur, 8–8–50, and were applied with coarse nozzles at a pressure of 100 pounds.

In experiment 1 the application was made May 24, when 95 per cent of the overwintered scales were mature. This spraying was both extensive and thorough, but was inefficient against the mature females and failed to control the sooty molds. Experiment 2 was directed against the larvæ during the beginning of the leafward migration, but gave an efficiency of only 15 per cent and also failed to control sooty molds.

In experiment 3 two applications were made, the first at the beginning of the leafward migration and the last when 95 per cent of the larvæ were upon the leaves. Both sprayings were ineffective and the small mortality (6.3 per cent) came entirely from the first application.

In experiment 4, 3 applications were made, when the leafward migration started, when 95 per cent were upon the leaves, and just before the twigward migration. These applications were also ineffective, and the mortality was no greater than in the case of experiment 1. The fungus was partly controlled, but the fruit was coated with lime to such an extent that the general effect was injurious rather than beneficial.

In experiments 5 and 6 tobacco extract was added to the self-boiled lime-sulphur, and the applications were made when 95 per cent of the larvæ were upon the leaves. These experiments gave no better results than the preceding ones and showed that tobacco extract is inefficient, at the strength used, when applied against the larvæ when they are upon the leaves.

In experiment 7 self-boiled lime-sulphur was modified to increase the thickness of the coating, and was directed against the young females. The branches of the young twigs were coated just before the females started their twigward migration. This experiment was ineffective.

Experiment 8 was made to test the smothering properties of Paris white and glucose. The application was made with a barrel pump, just before the females started migrating to the twigs. The spray was ineffective.

In experiment 9 a thick whitewash, to which casein had been added, was applied just before the young females started the twigward migration. The limbs were heavily coated, but the scales were not killed.

In experiment 10 pulverized china clay was used. It proved to be a poor coating material and was inefficient. Considered as a whole the experiments in Table XLIV indicate that self-boiled lime-sulphur is ineffective when applied at the time of the twigward migration,

both against the scale and the sooty molds. They also indicate that the other substances tested are ineffective against the terrapin scale.

The experiments with coating sprays performed in 1912 were failures, so far as controlling the terrapin scale was concerned, but they were valuable in showing that sulphur was the active component of self-boiled lime-sulphur and that its efficiency could be improved by increasing its spreading and sticking powers. It was evident also that sulphur was ineffective against the mature females.

COATING SPRAYS WITH FLOUR ADDED.

In 1913 experiments were made to perfect a coating spray by adding a spreader and sticker to self-boiled lime-sulphur and by increasing the sulphur content. The chief details and the results of these experiments are recorded in Table XLV.

In these experiments the flour was first made into a thin batter with cold water and then cooked to form a paste. The other ingredients were combined exactly as in making self-boiled lime-sulphur, after which the flour paste was added.

In the first four experiments the same spray was used. Experiment 1 was directed against the larvæ during the leafward migration and was very successful. Experiment 2 was directed both against leafward migrants and against the larvæ upon the leaves. It shows high efficiency, which is, however, entirely due to the first spraying, as is shown by the negative results in experiment 3.

Experiments 5, 6, 7, and 8 were performed with the same formula used in the preceding experiments, except that 1 pint of 40 per cent nicotine sulphate was added. The results from these experiments show that the nicotine adds nothing to the efficiency of the spray.

Experiment 9 was made with flour paste and shows that flour acts only as a spreader and adhesive and not as a killing agent.

Experiment 10 was made with modified self-boiled lime-sulphur to which flour paste was added, and was directed against the larvæ after they were well established upon the leaves. The spray was ineffective, as were all other applications made against the leaf-attached larvæ.

From these experiments it appears that the terrapin scale can be controlled by a coating spray applied against the larvæ during the leafward migration and that these sprays are inefficient at other times. Coating sprays are more difficult to apply than the oil sprays and require a first-class sprayer with a powerful agitator and plenty of pressure. Coarse-angle nozzles should be used and the underside of the leaves should be thoroughly drenched, and the spray must be applied just before the young emerge. The time for applying this spray, which is immediately after the appearance of young under the

scales, can best be determined by displacing a number of scales daily during the early part of June. In the region of Mont Alto, Pa., the young will appear under the scales about June 12. For this coating spray use the following formula:

	Pounds.
Stone lime	15
Sulphur	20
Flour	10
Water to make 50 gallons.	

The lime and sulphur are combined exactly as in making self-boiled lime-sulphur. The flour is made into a thin batter with cold water and cooked to a paste. It is then added to the lime-sulphur, and the whole should then be diluted to 50 gallons, when it is ready for use. Particular care must be taken to get a batter free from lumps; if this is done, and the spray is strained through a sieve, there will be no trouble in passing it through the nozzles. This spray when properly applied will kill from 94 to 100 per cent of the larvæ. It is effective only against the leafward migrating larvæ and is useless if applied after the larvæ have attached to the leaves.

SUMMARY.

SUMMARY OF LIFE HISTORY.

The female of the terrapin scale reaches maturity about the 1st of June and gives birth to living young soon afterwards. These are retained for a period of from 1 to 3 days in the brood chamber, which is a dome-shaped cavity beneath the scale. They then emerge and migrate at once to the underside of the leaves, where they settle, mostly along the midrib and the larger veins. The first instar, which lasts about 18 days, is vegetative and the larvæ show no sexual differentiation, but during the second instar, which also lasts about 18 days, sexual differentiation is very pronounced. At the end of this instar the female is very flat and circular, while the male, which is flat and decidedly oval, is protected by a conspicuous waxy structure called the puparium. After the second instar the sexes follow entirely different lines of development.

The female remains for 1 day upon the leaves after entering the third instar, which is the final instar for this sex. During this day it secretes a thin wax scale, which protects it during the twigward migration. At the beginning of this migration the female larvæ abandon the leaves and pass to the basal part of the new growth, where they make their final attachment within the area of greatest illumination. They then commence a period of rapid growth, during the first 11 days of which they develop their mating color, which is a conspicuous red band upon the middorsal line. At the time the dorsal band is completed the male migrates to the leaves, mates, and

dies. The female after mating starts a rapid growth during which the mating colors and the larval characters are lost and during which vast quantities of honeydew are deposited. By the end of the twentieth day upon the twig the female has assumed all the adult characters. After this, growth gradually slackens until the cold of the approaching winter forces the scale into hibernation. In the spring growth is resumed. Maturity is reached early in June and the scale dies early in July, after having lived about 13 months.

The male, which makes the second molt and passes all of its remaining instars, except the last day of the imago, under the protection of the puparium, loses its mouth-parts at this time and lives during the remainder of its life upon nourishment taken in the first two instars. The third or prepupal instar lasts about 2 days and is a period of rapid metamorphosis, in which the larval organs are replaced by the adult structures. In the fourth or pupal instar, which lasts for about 8 days, the adult organs reach their full development. At the fourth and final molt the imago escapes from the pupal case, but remains for about 2 days under the puparium before emerging, when it migrates at once to the twigs, copulates, and then dies, after having lived about 49 days.

SUMMARY OF REMEDIAL MEASURES.

An endeavor was made to prevent the soot injury which is the main cause of complaint from orchardists against this scale. During the first season one series of sprayings was made to control it in the presence of the living scale, and another series was made to control it by destroying the scale. It was found impracticable to control the "soot" directly. Accordingly in the second season all sprayings were made against the scale. Seven groups of materials were tested, the first of which contained corn oil, rosin oil, and gasoline. Of these, the two former were good treatments, but were very injurious to the trees. The latter was inefficient but gave promise as a wax solvent and penetrant.

Miscible Oils.

The second group contained miscible oils. Nine experiments were made with miscible oil, including 5 with miscible oil and gasoline, and 2 with miscible oil and nicotine.

In the first case it was evident that miscible oil was injurious when used in the winter at effective strengths, but that it could be used without injury if applied in the spring between the swelling and the bursting of the fruit buds. It was also evident that healthy 11-year-old trees could be sprayed for three consecutive seasons with miscible oil 1 to 18 without injury to the trees, and that the scale could be controlled by two seasons' spraying with this oil.

In the second case it was evident that combining gasoline emulsion and miscible oil added to the efficiency of the oil. The greatest efficiency was obtained when 5 parts of miscible oil were added to 3 parts of gasoline (emulsified) and 92 parts of water. In the third case it was evident that adding nicotine did not increase the efficiency of miscible oil.

Cottonseed Oil.

The third group consisted of 10 experiments made with cottonseed oil. This was a promising oil and both its penetration and wax-solvent powers were greatly increased by the addition of gasoline. The highest efficiency was obtained by using an emulsion containing

Cottonseed oil	5 gallons.
Gasoline	3 gallons.
Soap	2 pounds.
Water	92 gallons.

combined as indicated on page 67. This oil proved nearly as effective as linseed oil.

Linseed Oil.

The fourth group consists of 5 experiments made with raw linseed oil. It was soon evident that this oil was promising. It was very efficient when used alone as a 10 per cent emulsion, but it gave even better results when combined with gasoline. The gasoline component increases the fluidity of the oil, dissolves the protecting wax film, and tends to asphyxiate the scales. After the emulsion has penetrated to the underside of the scale this component evaporates, while the other component, after smothering the scale, becomes inert. In this respect it is superior to the oils ordinarily used against this scale. The best results are obtained by using an emulsion made up as follows:

Raw linseed oil	5 gallons.
Gasoline	3 gallons.
Laundry soap [1]	2 pounds.
Water	92 gallons.

When made as indicated on page 82, this emulsion applied in the spring before the buds burst will control the terrapin scale at a single application and at a cost for material of from 1 to 8 cents per tree. This was found to be the most effective treatment of any of the remedies tried against this insect.

Mixed Oils.

Group 5 contains only two experiments. They show conclusively that there is no advantage in mixing linseed and cottonseed oils.

[1] This is the minimum amount; more may be required if the soap is mild.

Nicotine.

In group 6 the efficiency of nicotine was tested in 14 experiments. Both the commercial sulphate and the aqueous solution were tested. This substance proved inefficient in all cases.

Coating Sprays.

In group 7 various coating sprays were tested. Twenty experiments were made. They were intended for the control of both the sooty fungus and the terrapin scale, but were ineffective against the "soot" in all cases where the insect was not killed.

From these experiments it is evident that the period in the life history of this insect when it can be most readily controlled by a coating spray is during the leafward migration. It is also evident that sulphur is the efficient component in the coating sprays, and that the ordinary self-boiled lime-sulphur lacked the spreading and adhesive properties necessary to make it an efficient coating spray. The modified formula given under "Recommendations" (second formula, below) was accordingly devised.

RECOMMENDATIONS FOR CONTROL.

Spray in the spring before the buds burst, with the following emulsion (see page 82):

Raw linseed oil	5 gallons.
Gasoline	3 gallons.
Soap	2 pounds.
Water	92 gallons.

If the foregoing formula is not used, spray with proprietary miscible oils, containing not less than 75 per cent mineral oil, at the rate of 1 part to 16 to 20 parts of water. Applications of this formula should likewise be made in the spring during the period between the swelling and the opening of the buds. (See pp. 68–73.)

To protect a crop after the trees are in foliage, spray just before the leafward migration (see pp. 19–24) with the following formula (p. 85):

Flour (in paste)	10 pounds.
Stone lime	15 pounds.
Sulphur	20 pounds.
Water to make	50 gallons.

This should be applied at the time the young appear in the brood chambers, but before they have emerged. This time can be best determined by making a daily examination of infested twigs. Since the young are not destroyed after they have attached, only one thorough application is advisable. This treatment, owing to the limited time for its application, is not as practicable as the dormant sprayings and should be used only in emergencies. This spray does not seriously coat the fruit.

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BULLETIN No. 352

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief.

Washington, D. C. PROFESSIONAL PAPER. May 5, 1916

THE CHERRY LEAF-BEETLE,[1] A PERIODICALLY IMPORTANT ENEMY OF CHERRIES.

By R. A. CUSHMAN, *Entomological Assistant*, and DWIGHT ISELY, *Scientific Assistant*, *Deciduous Fruit Insect Investigations.*

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INTRODUCTION.

The sudden appearance of enormous numbers of a small red beetle throughout a wide area in the northeastern United States in the spring of 1915 caused consternation among many of the fruit growers of that region. It attacked the foliage of cherry and peach trees and to some extent the fruit of the former. Its range of greatest destructiveness was in New York, Pennsylvania, and northern West Virginia. This insect is the so-called cherry leaf-beetle (*Galerucella cavicollis* LeC.) (fig. 1), a member of the family Chrysomelidæ, and is closely allied to the imported elm leaf-beetle (*G. luteola* Müller). At the time of its appearance practically nothing was known by fruit growers in regard either to its habits or its control, and comparatively little was known by entomologists. Sporadic outbreaks had occurred in the past, but references to them in entomological literature are brief. Taking advantage of this unusual outbreak, the writers have undertaken to secure as complete data as possible in regard to its natural food plants, its immature stages and

[1] *Galerucella cavicollis* LeConte; order Coleoptera, family Chrysomelidæ.

NOTE.—While this paper was going through the press an account of this insect appeared in the Journal of Agricultural Research under the authorship of Glenn W. Herrick and Robert Matheson of Cornell University.

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life history, and the means for its control. The work herein discussed was conducted at North East, Pa., during the season of 1915.

FOOD PLANTS.

In the region covered by the writers' observations the natural food plant of this insect is the pin, fire, or bird cherry (*Prunus pennsylvanica*). (Pl. I; Pl. V, *A* and *B*.) Wild black cherry (*P. serotina*) and chokecherry (*P. virginiana*) are entirely immune from attack, even by the beetles. Among cultivated fruits only sour cherry and peach trees are attacked. Even in the sour cherries those varieties, such as the Early Richmond, which have comparatively thin foliage, are much more seriously injured than the thicker leafed varieties. Sweet cherry and plum, common report to the contrary notwithstanding, are not at all eaten. The beetles have frequently been found on these trees, but never feeding. Color is lent to the belief that they attack plums by the very general prevalence of the shothole fungus on these trees, casual observers taking the holes caused by the fungus to be the feeding marks of the beetles.

FIG. 1.—Cherry leaf-beetle (*Galerucella cavicollis*): Adult beetle. Much enlarged; natural size at right. (Original.)

All of the foregoing observations in relation to cultivated trees apply to the adult beetle. On only one occasion were larvæ found on anything other than the pin cherry. On August 24 two larvæ were found on leaves of Early Richmond cherry. One of these had attained nearly full growth, while the other was still in the first stage. Neither of them lived to maturity. In the confinement of cages larvæ of the second and third stages fed sparingly on leaves of cultivated cherry, but first-stage larvæ died without feeding. One lot of 57 newly hatched larvæ were fed on peach leaves, but within 6 days all were dead.

From the records just given it appears that, except in the adult stage, this species is not likely ever to become of economic importance.

The beetles are mentioned in literature as having been taken on various other plants, such as apple and chestnut, but these were probably merely strays, although Davis (1896)[1] states definitely that they attacked apple in Michigan. The apple was, however, entirely immune to attack during the present outbreak.

Lugger (1899) mentioned "native plum" as a natural food plant as well as the "fire cherry."

The old idea that *G. rufosanguinea* Say is a Southern form of *cavicollis* together with an obvious mixing of data has led to the inclusion, in literature, of *Ranunculus acris*, a buttercup, among the host plants of *cavicollis*. *G. rufosanguinea* is known to breed on wild azalea.

[1] Dates in parentheses refer to the Bibliography, p. 25.

In a note entitled "Beetles on buttercup and azalea," in answer to a correspondent, Walsh (Pract. Ent., 1866, vol. 2, p. 9) determined *G. rufosanguinea* from *Ranunculus acris* and another beetle from *Azalea nudiflora*. Quite obviously the *G. rufosanguinea* should have been recorded from the azalea. Lintner (1896), quoting Walsh, says: "If the identification of Walsh was correct, it [i. e., *G. cavicollis*] has also been taken in June on buttercup, *Ranunculus acris*, in the vicinity of Albany, N. Y."

DISTRIBUTION.

Galerucella cavicollis is known to occur from Canada and the New England States west to Minnesota, and south along the Appalachians into West Virginia and Virginia. The type specimen is said to have come from North Carolina. It has been taken, according to Smith (1909), at Sea Isle and Anglesea, both localities near the southern point of New Jersey. According to Chittenden (1899), it has also been taken at Vancouver, British Columbia, and in Texas. It quite likely occurs throughout the natural range of its native host plant, *Prunus pennsylvanica*, which, according to Gray,[1] is "Lab. to B. C., S. to Pa., Great L. region, centr. Ia., and along mts. to N. C., Tenn., and Colo." Britton and Brown [2] add Georgia.

ECONOMIC HISTORY PREVIOUS TO 1915.

Economic injury by this beetle was first recorded in 1894 by Davis, who found it feeding on cultivated cherry at Bellaire, Mich. It was again reported the following year from Au Sable Forks, N. Y., by Lintner. In 1897 it was reported as destructive at Traverse City, Mich., by Pettit, and (1898) at Corning, N. Y., by Felt. The next year Chittenden (1899) recorded injury from St. Ignace, Mich., and Spruce Creek and Lebanon, Pa. Injury was observed by Harvey (1901) at Orono, Me., in 1900.

No outbreaks occurring after this time have been specifically recorded in entomological literature, although there are some general references to the beetle. However, economic injury was reported by correspondents to the Bureau of Entomology in 1912 from Newberry and Pontiac, Mich., and in 1914 from Muncy and Williamsport, Pa.

THE 1915 OUTBREAK.

EXTENT OF INJURY.

The 1915 outbreak was probably by far the most injurious that has ever occurred. Complaints regarding this pest were much more numerous and from many more localities than those from all preceding years combined. The beetle, instead of inflicting injury in a few

[1] New Manual of Botany (7th edition). [2] Illustrated Flora of the United States and Canada.

restricted localities, was generally destructive throughout two comparatively large regions; the one, in the Appalachian region, involving the greater part of New York, Pennsylvania, and northern West Virginia; the other in the northern part of lower Michigan, especially in the Grand Traverse region, where cherry growing is very extensive. In regard to the latter region Prof. R. H. Pettit, of the Michigan Agricultural College, writes (in litt.) that during the period of destructiveness by this beetle nearly every mail brought complaints. No complaints were received by the Bureau of Entomology from the territory intervening between these two regions. One of the writers, on June 17 and 18, traveled by trolley through Ohio from Sandusky to Ashtabula, stopping at a number of points between, and no injury by these beetles was noted.

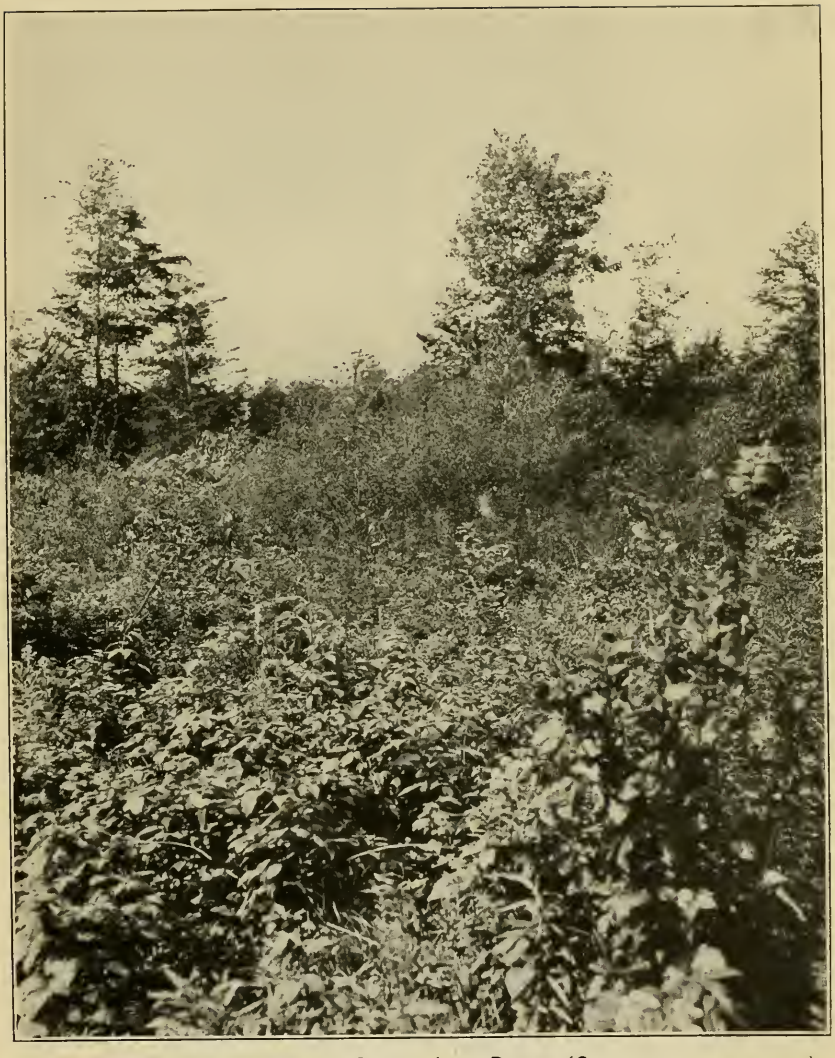
The majority of complaints came in June. However, the beetle was reported from Jamestown, N. Y., as early as May 12, and from Williamsport, Pa., May 21. The general migration to cultivated food plants in northwestern New York and Pennsylvania did not occur until the week of June 7. Farther south, in West Virginia, it occurred about the same time, the first report having been sent June 9.

THE 1915 INVASION OF THE LAKE ERIE GRAPE BELT.

The beetles appeared in the vicinity of North East, Pa., on June 7, literally covering the leaves of the trees attacked. Early in the morning their advent attracted the attention of fruit growers living 3 or 4 miles south of Lake Erie, and by noon they were found in great numbers in orchards near the lake. After this first day of migration the increase was comparatively small, and no increase at all was noticeable in the vicinity at large after June 9, although there was some local shifting of numbers.

During the first few days of the migration stories told by fishermen of the abundance of the beetle on the lake were current; how pieces of wood floating on the water had been covered with them; how they had crowded on black buoys until the color of the buoys had been changed to red; and how the water itself had been full of them. But even after giving these stories the full discount that is generally accorded to stories of like origin, the fact still remains that the migration of great numbers of beetles extended for some distance over the lake. Dead beetles were found in considerable numbers on two of the lake beaches by one of the writers on June 10, when a strong north wind was blowing, and it was reported that they had been washed up in windrows. The occurrence of these beetles in the lake gave rise to the opinion that they had come from Canada.

The actual source of the beetles was to the south of the grape belt, from cut-over forest land grown over by pin cherry. The preceding



TYPICAL BREEDING GROUND OF THE CHERRY LEAF-BEETLE (GALERUCELLA CAVICOLLIS).

A group of pin-cherry bushes stands in the center of the picture. (Original.)

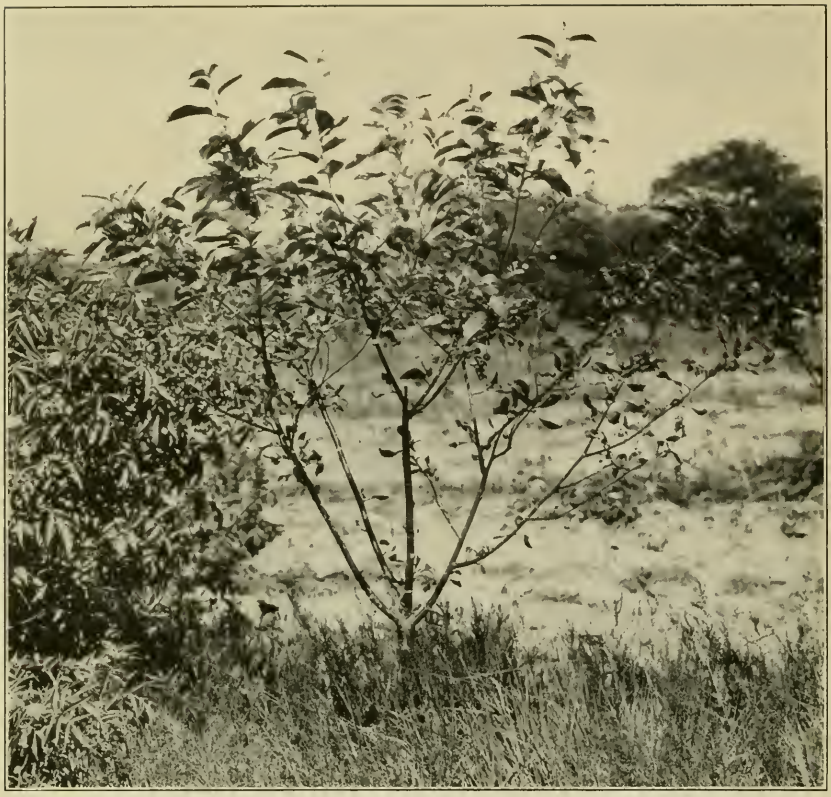


FIG. 1.—COMPARATIVE INJURY TO LOWER AND UPPER BRANCHES. (ORIGINAL.)

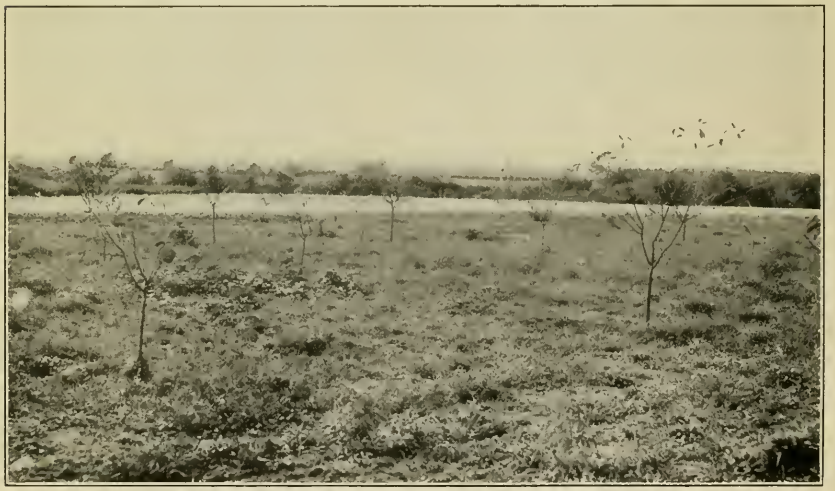
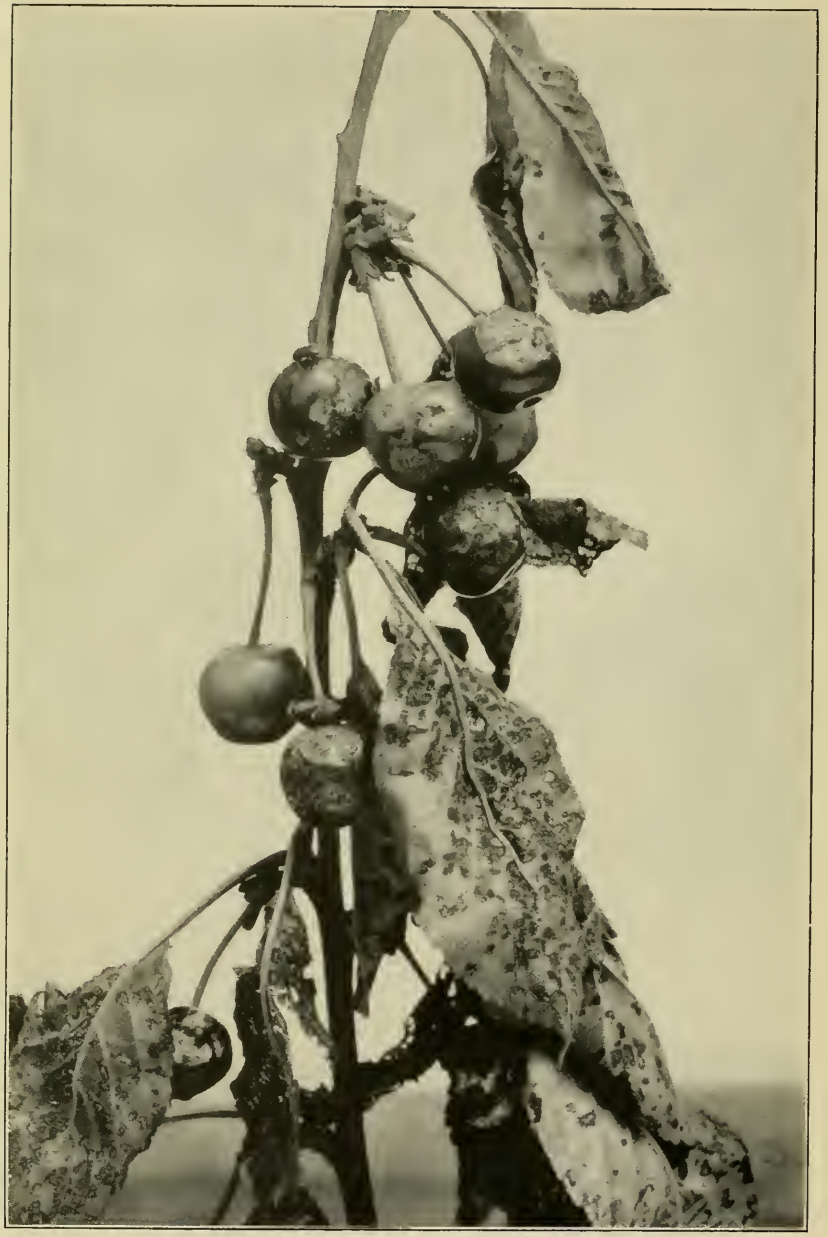


FIG. 2.—A YOUNG ORCHARD DEFOLIATED. (ORIGINAL.)

DEFOLIATION BY THE CHERRY LEAF-BEETLE OF YOUNG RICHMOND CHERRY TREES.

INJURY TO FOLIAGE AND FRUIT OF CHERRY BY THE CHERRY LEAF-BEETLE. (ORIGINAL.)



INJURY TO FOLIAGE AND FRUIT OF CHERRY BY THE CHERRY LEAF-BEETLE. (ORIGINAL.)

THE CHERRY LEAF-BEETLE.

Figures *A* and *B* show the effect of feeding of the cherry leaf-beetle on pin cherry. Figures *C* and *D* show beetles feeding on leaves of cultivated cherry. (Original.)

season had undoubtedly been favorable to the development of unusual numbers of these beetles—as much as their native host plant could support. Furthermore, the foliage of the pin cherry was reduced by a freeze on May 27, and perhaps in a part of the range by tent caterpillars also. Similar conditions were probably responsible for the outbreak in Michigan. These conditions induced a migration which was given direction by a strong wind that blew from the southeast and south on June 5, 6, and 7. It is probable that the majority of the beetles had emerged from hibernation and had been feeding for some time before their advent in the grape belt, for an outbreak was reported from Jamestown, N. Y., about 25 miles south of Lake Erie, as early as May 12.

Within a few days after their arrival the numbers of the beetles began to decrease in some orchards, and in two weeks this was general. By the latter part of June practically all had disappeared from the orchards, although a few scattering ones were found as late as early August.

CAUSE OF INCREASE OF BEETLES.

The increased numbers of the cherry leaf-beetle may be attributed to an increase in abundance of its natural food plant, the pin cherry. This tree springs up rapidly along roadsides and in cut-over or fire-swept forest land which has been left uncultivated. Such lands cover wide areas in western Pennsylvania, and furnish ideal breeding conditions for the beetle. A typical view of such a situation is shown in Plate I.

FEEDING HABITS AND DESTRUCTIVENESS.

The adult cherry leaf-beetle feeds almost exclusively on the underside of the leaves of the plants attacked (Pl. V, *C, D*), eating small, irregular holes through the lower epidermis and parenchyma and sometimes through the entire leaf. These holes may join one another or come so close together as to skeletonize the leaf. In a few days after feeding, the upper epidermis thus exposed dries and falls out, and, in case of severe injury, the whole leaf dries, and defoliation ensues. To an extent it feeds also upon the fruit of the cherry, scarring and pitting it. (Pls. III, IV.)

On cold days and at night the beetles crowd on the upper surface of the leaves, and hence have given the impression that they feed there. Occasionally the writers have found beetles feeding on the upper surface of peach leaves, usually those attacked by leaf curl, and once on the upper surface of cherry leaves. The misapprehension in regard to their feeding on plum has been discussed in an earlier paragraph. The shot-hole fungus, responsible for this mistaken belief, also attacks other stone fruits which the beetle attacks, and

caused the impression that the injury by the beetle was greater than really was the case.

The larvæ of all ages feed in a manner similar to the adults, on the under surface, eating through the leaf to the upper epidermis, but leaving that intact. Occasionally a first-stage larva is found feeding on the upper surface, but this occurs only on very young leaves that have not entirely unfolded.

The feeding preference for sickly or injured trees was marked. Such trees were invariably loaded with beetles, while the surrounding trees may have been comparatively free from attack. The foliage on an unhealthy branch was attacked before the rest of the tree. The preference for the foliage on the lower limbs to that of the upper was still more conspicuous, for the lower limbs may have been completely defoliated, while the foliage of the upper limbs was comparatively uninjured. (Pl. II.)

The period of economic injury due to this beetle extended over 14 or 18 days after its first appearance in June. Probably the greater part of the feeding was done during the first three or four days. There was no injury noticeable from the later brood.

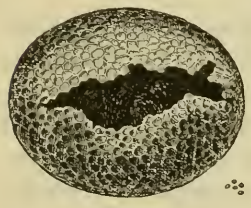


FIG. 2.—The cherry leaf-beetle: Egg. Much enlarged. (Original.)

Severe injury due to this beetle was confined almost entirely to the Early Richmond cherry, especially to young trees. (Pl. II.) In a few young orchards, within four days after the first appearance of the beetles, the foliage on the lower half of the trees was a withered brown, as if it had been burned. In two weeks the trees were almost completely defoliated. On peach and other varieties of cherry trees, although in some instances the feeding appeared quite severe, there was little defoliation.

DESCRIPTION OF STAGES.

THE EGG.

The egg (fig. 2) was first described by Chittenden (1899). It is nearly spherical and bright reddish brown and has the surface deeply pitted with irregularly hexagonal areas. The eggs vary somewhat in size and proportions, but average about 0.75 mm. long by 0.65 mm. in width.

THE LARVA.

Except for the increase in size, all three larval instars are very similar. In the early part of each instar the larva is nearly uniform, very dark olive in color, about three times as long as broad, and with short stout legs. It is broadest at the prothorax, which is about twice as broad as the nearly hemispherical head, and tapers backward to the ninth abdominal segment, which is slightly narrower than the head. Each of the three thoracic and the first eight abdominal segments are more or less conically produced at the sides and bear long bristles extending laterally. Dorsally there are transverse rows of short bristles across the front of the prothorax and double rows across each of

the other thoracic segments, and all abdominal segments except the ninth and tenth. The head is provided with a few scattered long bristles. The ninth abdominal segment is rounded behind and concave above, very heavily chitinized, and with a row of long bristles around the edge. Below it is rather conical, with the very small tenth segment forming the apex of the cone. The latter bears the anus, which is modified to form an auxiliary organ of locomotion. On each side, between the prothoracic and mesothoracic segments, can be seen a small tubercle surrounding the mesothoracic spiracle, and each of the first eight abdominal segments is provided with a pair of spiracles. On each side of the middle the prothorax is irregularly impressed. This concavity persists through all stages.

FIG. 3.—The cherry leaf-beetle: Newly hatched larva. Much enlarged. (Original.)

At full growth (fig. 4) each instar is very much distended, the yellowish skin becomes visible, and the dark color is confined to plates and patches, the head, and the legs. The abdomen is parallel sided and wider than the thorax. The head and ninth abdominal segment, at least above, do not share in this distension, but retain the size originally assumed after the molt. The dorsal surface of the prothorax is covered by a single large, dark-colored plate, flanked on either side by the dark colored, chitinized tips of the lateral prominences. Just below the latter are two small plates partially surrounding the base of the coxa. Ventrally the dark color is confined to a nearly square median patch with a very small oval patch behind it. In the mesothoracic and metathoracic segments the dorsal plate is broken up into two double transverse rows of three plates each, the middle one in each row being much the largest, and transversely elongate. The lateral edges of the dorsum are very heavily chitinized and dark colored. Below the latter are two smaller plates, the anterior one of which on the mesothorax bears the spiracle, the other being the tip of the lateral prominence. Each of the coxæ is partially surrounded above by two small plates as in the prothorax. Ventrally there are three plates, a large transverse anterior one and a pair of small, nearly oval ones posteriorly. The dorsal plate of each of the first eight abdominal segments is similar to that of the mesothorax and of the metathorax, being broken up into two double rows of plates, but on the lateral edge of the dorsum are two very small plates, the posterior one of which bears the spiracle. Beyond these is the chitinized apex of the lateral prominence. Below the color is distributed in a transverse row of five spots. The ninth segment has ventrally a crescent-shaped plate in front of and partially surrounding the very small tenth segment, which bears the anus. The tenth segment is heavily chitinized laterally and posteriorly. (Fig. 5.)

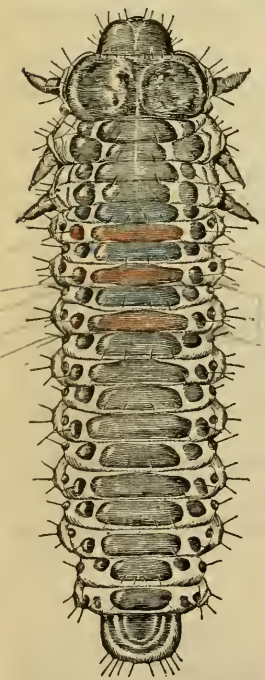


FIG. 4.—The cherry leaf-beetle: Full grown larva. Much enlarged. (Original.)

The newly hatched larva is shown in figure 3. The comparative size of the three larval stages is indicated by figure 6, which shows the heads and ninth abdominal segments drawn to the same scale.

First instar.—The first larval instar (fig. 3) varies with age from 2 to 3 mm. in length with the head 0.38 mm. and the ninth segment 0.36 mm. broad. (Fig. 6, *a*.)

Second instar.—Immediately after the first molt the second instar is about 3 mm. long, and at full growth 4.5 mm. long. The head is 0.57 mm. and the ninth abdominal segment 0.5 mm. broad. (Fig 6, *b*.)

Third instar.—The newly molted larva of the third instar is 4.5 mm. long with the head 0.78 mm. and the ninth segment 0.7 mm. broad. At full growth (fig. 4) it is 7 mm. long and the measurements of head and caudal segment are unchanged. (Fig. 6, *c*.)

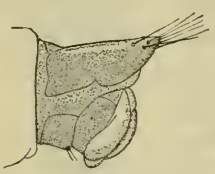


FIG. 5.—The cherry leaf-beetle: Eighth and ninth abdominal segments, lateral view, showing extruded end of alimentary canal used as auxiliary organ of locomotion. Much enlarged. (Original.)

THE PUPA.

The pupa (fig. 7) is slightly less than 5 mm. long, bright yellow, and with a pair of strong curved spines at the apex of the abdomen. The prothorax has the concavity characteristic of all stages of the species. The head has a curved row of four bristles above, the concave side of the curve to the front. On the pronotum are two rows of four bristles each, the anterior one curved to the front and the posterior one to the rear, and in addition a long bristle on each lateral angle and two near the posterior edge. The scutellum and metanotum each have a nearly straight row of four bristles. Each of the abdominal segments, except the last, has a pair of small bristles near the middle, and a single long bristle at each lateral angle. Each femur has a pair of apical bristles. The spiracles of the first five abdominal segments and of the mesothorax are conspicuous from their black color; the outer ends

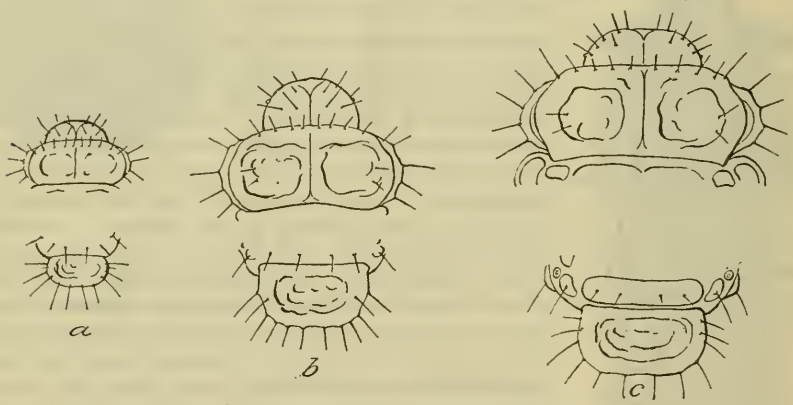


FIG. 6.—The cherry leaf-beetle: Larval heads and caudal segments, showing proportional size in the three instars: *a*, First instar; *b*, second instar; *c*, third instar. Greatly enlarged. (Original.)

of the tracheæ show black through the body wall for a short distance. The spiracles of the sixth and seventh segments are paler.

THE ADULT.

The adult beetle is rather oval in shape, about one-sixth of an inch long by about one-half as broad, and somewhat flattened. It is dull red with black legs and antennæ.

As Le Conte's original description of the species is in Latin, the description given by Horn (1893) is quoted below:

G. cavicollis Lec., Proc. Acad. 1865, p. 216. Oval, narrower in front, subdepressed; color dull red, slightly shining, very sparsely finely pubescent. Antennæ entirely

black. Head red, coarsely punctured, without median depression, frontal tubercles smooth. Thorax nearly twice as wide as long, narrower in front, sides arcuate, or obtusely subangulate, hind angles distinct, base on each side obliquely sinuate, disc feebly convex, a broad depression each side and another along the middle, surface coarsely punctured, more densely in the depressions; scutellum red; elytra broader behind the middle, sides arcuate, margin explanate, humeri distinct, but rounded; sutural angle well marked, but obtuse; disc with coarse and deep punctures not crowded, less deep near the apex, interspaces smooth, shining. Body beneath red, the metasternum often piceous, sparsely finely punctate and finely pubescent. Legs variable in color entirely red to almost entirely piceous. Length .18–.22 inch; 4.5–5.5 mm.

Male.—Claws finely bifid at apex. Last ventral segment broadly emarginate at apex, with a deep triangular depression limited by a sharply elevated line.

Female.—Claws more deeply bifid, the parts more divergent. Last ventral segment with a very slight emargination, in front of which is a slight fovea.

The middle coxæ are absolutely contiguous, the mesosternum is not prolonged between them, except as to the color of the legs no variation has been observed in this species.

FIG. 7.—The cherry leaf-beetle: Pupa. Much enlarged. (Original.)

LIFE HISTORY.

In the life-history work data were obtained on nearly 600 individuals, almost half of which were carried through their entire development from hatching to emergence of the adult insect. Daily observations were made and recorded, so that all transformations were noted within 24 hours of their occurrence.

It should be noted that the period—August and the first half of September—covered by these observations was one of unusually low temperature and high humidity for the season. In August there was at Erie, 16 miles west of North East, an average daily deficiency in temperature of 2.3° F. and an excess in precipitation over the normal, for the month, of 6.02 inches. In September the temperature was higher, but the precipitation was still abnormally high. The life-history periods shown by this data, therefore, are probably somewhat longer than the normal for the species.

The life-history work was carried on in 1-inch vials, the larvæ being supplied daily with fresh leaves of pin cherry. For pupation about 1½ inches of earth was supplied. For larger lots jelly tumblers were used. Very few of the individuals failed to mature and emerge as beetles.

THE ADULT BEETLE.

Reaching the adult stage in the late summer and early fall, the beetles feed for a few weeks, and then seek out a protected situation in which they pass the winter. According to Pettit (1904) the beetles pass the winter several inches below the surface of the ground. Emerging from hibernation in the spring, they feed again for some time, mate, and the females descend to the base of the trees, where, among the decaying leaves and other vegetable matter, they deposit their eggs. Occasionally they utilize for this purpose accumulations of rubbish in the cavities in the bark of large trees. In such situations eggs have been found as high as 4 feet above the ground.

INCUBATION PERIOD.

No definite data on the incubation period were obtained, but on August 3 and 5 two lots of eggs were collected and placed in vials with the rubbish on which they were deposited. Most of those of August 3 had already hatched, but young larvæ continued to emerge until August 14, 11 days after the collection of the eggs. This lot was collected on the hills about 4 miles back from the lake. The lot of August 5 was collected only about a mile from the lake, and included a much smaller percentage of hatched eggs. This lot continued to produce larvæ until August 18, 13 days after collection. These figures are probably very near to the incubation period for the season of 1915, since Chittenden (1899) records a period of 11 days in 1898 at Washington, D. C.

THE LARVA.

In hatching the larva cuts an irregular slit in one side of the egg. It then ascends the tree, and, feeding on the underside of the leaf, grows very rapidly. During its feeding period it molts twice. In molting the skin splits down the middle line of the thorax, the split extending on to the head, where it divides and extends to each side of the mouth. The head, thorax, and appendages are withdrawn, and the larva secures a hold on the leaf with its feet and crawls out of its old skin, which remains for some time fastened to the leaf.

First instar.—In the course of the life-history work 243 larvæ were carried through the first instar. Of these 79 required 4 days; 140, 5 days; 17, 6 days; 5, 7 days; 1, 10 days; and 1, 11 days. This gives an average period for the first instar of 4.83 days. The first of these hatched on August 5 and the last molted for the first time on August 24, this being the period in which all the data on this instar were obtained. Table I summarizes these data.

TABLE I.—*Period of first larval instar of the cherry leaf-beetle at North East, Pa., 1915.*

Number of individuals.	Duration of first larval instar.
	Days.
79	4
140	5
17	6
5	7
1	10
1	11
243	[1] 4.83

[1] Average.

Second instar.—Data for the duration of the second instar were obtained from observations on 268 larvæ. The period covered by these observations was from August 6, when the earliest first molt took place, to August 29, when the last one molted for the second time. Table II shows the results obtained:

TABLE II.—*Period of second larval instar of the cherry leaf-beetle at North East, Pa., 1915.*

Number of individuals.	Duration of second larval instar.
	Days.
145	3
100	4
18	5
5	6
1	7
269	[1] 3.58

[1] Average.

Third instar.—When the larva becomes full grown it leaves the tree, burrows into the soil for a fraction of an inch, and constructs its pupal cell. That portion of its life between its second molt and its entrance into the ground—that is, the feeding period of this instar—was determined for 349 larvæ, with the results given in Table III. The first of these to molt for the second time did so on August 7, and the last one entered the ground on September 5.

TABLE III.—*Feeding period of third larval instar of the cherry leaf-beetle, North East, Pa., 1915.*

Number of individuals.	Feeding period of third larval instar.
	Days.
64	3
211	4
55	5
8	6
8	7
3	8
349	[1] 4.12

[1] Average.

Total feeding period.—A total of 227 larvæ were carried through the entire feeding period from hatching to entrance into the ground. Table IV contains the data obtained. These data were obtained during the period from August 5, when the first one hatched, to September 5, when the last one entered the ground.

TABLE IV.—*Total feeding period of larvæ of the cherry leaf-beetle, North East, Pa., 1915.*

Number of individuals.	Total feeding period.	Number of individuals.	Total feeding period.
	Days.		*Days.*
3	10	1	16
49	11	2	17
115	12	5	18
36	13	2	20
7	14		
7	15	227	[1] 12.33

[1] Average.

PERIOD IN GROUND.

The pupal cell is nearly spherical and about 5 mm. in diameter. It is from a fourth to a half inch below the surface. Within it the insect passes through the transformations from larva to pupa and from pupa to adult. The larva lies for several days curled up as shown in figure 8 before transforming to the pupa.

FIG. 8.—The cherry leaf-beetle: Prepupal larva. (Original.)

Data on the dates of transformation of the larva are difficult to obtain, since this necessarily involves the breaking up of the pupal cell, and such data as were obtained are based on but few individuals.

Prepupal period.—In a lot of larvæ that entered the ground on August 5 daily examination showed that the first one pupated on August 13, or 8 days later. On the same day 1 pupa was found among larvæ that entered the ground on August 6, giving a prepupal period of 7 days. One out of 3 larvæ that entered the ground on August 7 had pupated 7 days later, on August 14. Larvæ that entered the ground on September 4 and 5, when the weather was much warmer than in August, required only 5 days to pupate.

Pupal period.—In the August lots just mentioned the first transformation to the adult stage took place 9 days after the first pupation, while in the September lots the pupal period was only 7 or 8 days. In a lot which entered the ground on August 22 the first one pupated on September 10, 19 days later. Unfortunately, the prepupal period for these was not determined, but as that period was passed during the very cold days of late August, it was undoubtedly longer than in the earlier and later lots, and the pupal period was probably close to 11 days in length.

Emergence of the adults takes place from a day to several days after transformation.

Total period in ground.—Five hundred and sixty-three individuals were carried through this period of their development, the time required varying from 14 to 28 days, with the greatest emergence on the twenty-second day. Table V gives the data on this point.

TABLE V.—*Total period spent in the ground by stages of the cherry leaf-beetle.*

Number of individuals.	Period in ground.	Number of individuals.	Period in ground.
	Days.		*Days.*
2	14	116	23
1	15	47	24
1	16	62	25
1	17	30	26
9	18	3	27
44	19	1	28
30	20		
68	21	563	[1] 22.36
148	22		

[1] Average.

The males required on the average 0.1 of a day longer than the females, the average for the males being 22.41 days and for the females 22.31 days.

DEVELOPMENTAL PERIOD.

The total developmental period, exclusive of the incubation period, of 218 individuals was obtained. This varied from 31 to 40 days, with the heaviest emergence on the thirty-third and thirty-fourth days. Table VI gives the data obtained.

TABLE VI.—*Total developmental period of the cherry leaf-beetle, exclusive of the incubation period, North East, Pa., 1915.*

Number of individuals.	Developmental period.	Number of individuals.	Developmental period.
	Days.		*Days.*
3	31	2	37
27	32	1	39
67	33	1	40
63	34		
45	35	218	[1] 33.76
9	36		

[1] Average

The males required 33.81 days and the females 33.73 days. Allowing an incubation period of 11 days the total developmental period would be in the neighborhood of 45 days. Table VII gives in more detail all the life-history data obtained.

TABLE VII.—*Developmental period of the cherry leaf-beetle exclusive of the incubation period, North East, Pa., 1915.*

Lot No.	Date hatched.	Date first molt.	Number of individuals.	First stage duration.	Date second molt.	Number of individuals.	Second stage duration.	Date in ground.	Number of individuals.	Feeding period, third stage.	Total feeding period.	Date adults emerged.	Number of—		Period in ground.	Period from hatching to emergence of adults.
													Male.	Female.		
				Days.			*Days.*			*Days.*	*Days.*				*Days.*	*Days.*
2								Aug. 5				Aug. 23	3		18	
												Aug. 24	2	6	19	
												Aug. 28	1		23	
6								Aug. 6				Aug. 24	2		18	
												Aug. 25	9	19	19	
												Aug. 26	3		20	
												Aug. 27	4	4	21	
												Aug. 28	6	8	22	
												Aug. 29	4	4	23	
												Aug. 30	1		24	
9								Aug. 7				Aug. 29	7	12	22	
												Aug. 30	9	14	23	
												Aug. 31	7	2	24	
												Sept. 1	5	4	25	
												Sept. 2	4	8	26	
												Sept. 3		3	27	
												Sept. 4	1		28	
11								Aug. 8				Aug. 26		1	18	
												Aug. 28	2		20	
												Aug. 30	1		22	
												Aug. 31	2	1	23	
												Sept. 1	3	1	24	
												Sept. 2	19	12	25	
												Sept. 3	6	11	26	
17								Aug. 9				Aug. 29	1	1	20	
												Aug. 30	1		20	
												Aug. 31		2	22	
												Sept. 1	2	1	23	
												Sept. 2	6	11	24	
												Sept. 3	12	10	25	
												Sept. 4	1		26	
8					Aug. 7			Aug. 11	23	4		Sept. 2	2	2	22	
												Sept. 3	4	7	23	
												Sept. 4	3	3	24	
								Aug. 12	3	5		Sept. 1	1		20	
												Sept. 4	1		23	
								Aug. 13	1	6		Sept. 3		1	21	
								Aug. 14	1	7		Sept. 5	1		22	

12	.....	.....	.....	.....	Aug. 8	.....	.....	Aug. 11	6	3	.....	Sept. 2	.....	1	22	.....		
												Sept. 3	1	1	23	.....		
												Sept. 4	.....	1	24	.....		
								Aug. 12	24	4	.....	Sept. 3	5	4	22	.....		
												Sept. 4	5	2	23	.....		
												Sept. 5	2	.....	24	.....		
								Aug. 13	11	[1] 5	.....	.....	.....	.....	.....	.....		
								Aug. 14	4	6	.....	Sept. 5	.....	2	22	.....		
												Sept. 6	.....	1	23	.....		
16	.....	.....	.....	.....	Aug. 9	.....	.....	Aug. 13	6	4	.....	Sept. 4	.....	1	22	.....		
												Sept. 5	1	1	23	.....		
								Aug. 14	5	5	.....	Sept. 5	3	1	22	.....		
												Sept. 6	.....	1	23	.....		
								Aug. 16	5	7	.....	Sept. 6	2	1	21	.....		
												Sept. 8	.....	2	23	.....		
3	.....	Aug. 6	.....	.....	Aug. 10	1	4	Aug. 14	1	4	.....	Sept. 7	.....	1	24	.....		
					Aug. 11	1	5	Aug. 15	1	4	.....	Sept. 6	1	.....	22	.....		
4	.....	Aug. 5	.....	.....	Aug. 10	1	5	Aug. 15	1	5	.....	.....	.....	.....	.....	.....		
7	.....	Aug. 7	.....	.....	Aug. 11	8	4	Aug. 14	3	3	.....	Sept. 5	1	2	22	.....		
								Aug. 15	5	4	.....	Sept. 6	.....	1	22	.....		
												Sept. 7	2	1	23	.....		
												Sept. 8	1	.....	24	.....		
					Aug. 12	2	5	Aug. 15	2	3	.....	Sept. 7	1	1	23	.....		
13	.....	Aug. 8	.....	.....	Aug. 12	5	4	Aug. 16	5	4	.....	Sept. 7	2	1	22	.....		
												Sept. 8	.....	1	23	.....		
												Sept. 9	1	.....	24	.....		
					Aug. 13	1	5	Aug. 18	1	5	.....	Sept. 11	1	.....	24	.....		
					Aug. 14	1	6	Aug. 19	1	5	.....	.....	.....	.....	.....	.....		
15	.....	Aug. 9	.....	.....	Aug. 12	2	3	Aug. 16	2	4	.....	Sept. 7	.....	1	22	.....		
												Sept. 8	.....	1	23	.....		
					Aug. 13	5	4	Aug. 16	2	3	.....	Sept. 7	1	.....	22	.....		
												Sept. 8	1	.....	23	.....		
								Aug. 17	1	4	.....	Sept. 9	1	.....	23	.....		
								Aug. 18	2	5	.....	Sept. 9	1	.....	22	.....		
												Sept. 10	.....	1	23	.....		
					Aug. 14	1	5	Aug. 17	1	3	.....	Sept. 8	1	.....	22	.....		
					Aug. 15	3	6	Aug. 19	1	4	.....	Sept. 10	.....	1	22	.....		
								Aug. 21	2	6	.....	Sept. 11	.....	1	21	.....		
												Sept. 12	1	.....	22	.....		
5	Aug. 6	Aug. 11	21	5	Aug. 14	16	3	Aug. 17	4	3	11	Sept. 8	2	2	22	33		
								Aug. 18	12	4	12	Sept. 8	1	.....	21	33		
												Sept. 9	3	4	22	34		
												Sept. 10	3	.....	23	35		
												Sept. 11	1	.....	24	36		
					Aug. 15	5	4	Aug. 18	2	3	12	Sept. 9	.....	2	22	34		
								Aug. 19	3	4	13	Sept. 9	1	.....	21	34		
												Sept. 10	1	1	22	35		
		Aug. 12	11	6	Aug. 15	8	3	Aug. 18	3	3	12	Sept. 10	3	.....	23	35		
								Aug. 19	4	4	13	Sept. 10	2	2	22	35		

[1] Not carried further.

TABLE VII.—*Developmental period of the cherry leaf-beetle exclusive of the incubation period, North East, Pa., 1915*—Continued.

Lot No.	Date hatched.	Date first molt.	Number of individuals.	First stage duration.	Date second molt.	Number of individuals.	Second stage duration.	Date in ground.	Number of individuals.	Feeding period, third stage.	Total feeding period.	Date adults emerged.	Number of—		Period in ground.	Period from hatching to emergence of adults.
													Male.	Female.		
				Days.			*Days.*			*Days.*	*Days.*				*Days.*	*Days.*
5					Aug. 16	3	4	Aug. 19	1	3	13	Sept. 10	.....	1	22	35
								Aug. 20	2	4	14	Sept. 10	1	.....	21	35
												Sept. 11	1	.....	23	36
		Aug. 13	2	7	Aug. 16	1	3	Aug. 21	1	5	15	Sept. 11	1	.....	21	36
					Aug. 17	1	4	Aug. 21	1	4	15	Sept. 11	1	.....	21	36
		Aug. 16	1	10	Aug. 21	1	5	Aug. 24	1	3	18	Sept. 14	1	.....	21	39
		Aug. 17	1	11	Aug. 21	1	4	Aug. 26	1	5	20	Sept. 15	1	.....	20	40
10	Aug. 7	Aug. 11	1	4	Aug. 15	1	4	Aug. 18	1	3	11	Sept. 10	1	.....	23	34
		Aug. 12	46	5	Aug. 15	41	3	Aug. 18	13	3	11	Sept. 9	3	2	22	33
												Sept. 10	5	1	23	34
												Sept. 11	1	.....	24	35
								Aug. 19	22	4	12	Sept. 10	4	10	22	34
												Sept. 11	3	4	23	35
												Sept. 12	.....	1	24	36
								Aug. 20	6	5	13	Sept. 10	2	.....	21	34
												Sept. 11	1	3	22	35
					Aug. 16	3	4	Aug. 19	3	3	12	Sept. 10	1	2	22	34
		Aug. 13	2	6	Aug. 16	2	3	Aug. 20	2	4	13	Sept. 12	1	1	23	36
		Aug. 14	1	7	Aug. 18	1	4	Aug. 23	1	5	16	Sept. 13	1	.....	21	37
14	Aug. 8	Aug. 12	22	4	Aug. 15	11	3	Aug. 18	3	3	10	Sept. 10	1	2	23	33
								Aug. 19	8	4	11	Sept. 9	.....	1	21	32
												Sept. 10	4	2	22	33
					Aug. 16	11	4	Aug. 9	3	3	11	Sept. 10	2	.....	22	33
												Sept. 11	.....	1	23	34
								Aug. 20	8	4	12	Sept. 10	4	1	21	33
												Sept. 11	1	.....	22	34
												Sept. 12	1	1	23	35
		Aug. 13	45	5	Aug. 16	36	3	Aug. 19	8	3	11	Sept. 10	2	5	22	33
								Aug. 20	27	4	12	Sept. 10	2	1	21	33
												Sept. 11	8	7	22	34
												Sept. 12	1	3	23	35
								Aug. 22	1	6	14	Sept. 12	1	1	21	35
					Aug. 17	9	4	Aug. 20	8	3	12	Sept. 12	2	6	23	35
		Aug. 14	2	6	Aug. 17	1	3	Aug. 21	1	4	13	Sept. 12	.....	1	22	35
					Aug. 18	1	4	Aug. 23	1	5	15	Sept. 13	.....	1	21	36
18	Aug. 11	Aug. 15	19	4	Aug. 18	14	3	Aug. 22	8	4	11	Sept. 12	2	5	21	32
								Aug. 23	6	5	12	Sept. 12	5	1	20	32
					Aug. 19	5	4	Aug. 23	3	4	12	Sept. 12	1	.....	20	32
												Sept. 13	.....	1	21	33
												Sept. 14	1	.....	22	34

								Aug. 24	2	5	13	Sept. 14	1	1	21	34
		Aug. 16	4	5	Aug. 19	4	3	Aug. 24	4	5	13	Sept. 13	.....	2	20	33
												Sept. 14	1	1	21	34
19	Aug. 12	Aug. 16	17	4	Aug. 19	5	3	Aug. 23	5	4	11	Sept. 12	1	.....	20	31
												Sept. 13	2	1	21	32
					Aug. 20	11	4	Aug. 24	10	4	12	Sept. 14	4	3	21	33
												Sept. 15	2	.....	22	34
		Aug. 17	10	5	Aug. 20	4	3	Aug. 24	4	4	12	Sept. 14	.....	1	21	33
												Sept. 15	2	1	22	34
					Aug. 21	4	4	Aug. 25	4	4	13	Sept. 14	1	1	20	33
												Sept. 16	.....	2	22	35
		Aug. 19	1	7	Aug. 24	1	5	Aug. 29	1	5	17	Sept. 18	.....	1	20	37
20	Aug. 13	Aug. 17	12	4	Aug. 21	10	4	Aug. 25	10	4	12	Sept. 14	.....	1	20	32
												Sept. 15	4	5	21	33
					Aug. 22	2	5	Aug. 26	2	4	13	Sept. 15	.....	1	20	33
												Sept. 16	1	.....	21	34
		Aug. 18	5	5	Aug. 22	1	4	Aug. 27	1	5	14	Sept. 16	1	.....	20	34
					Aug. 23	2	5	Aug. 28	2	5	15	Sept. 16	.....	2	19	34
					Aug. 24	1	6	Aug. 30	1	6	17	Sept. 17	.....	1	18	35
					Aug. 25	1	7	Sept. 2	1	8	20	Sept. 18	1	.....	16	36
21	Aug. 14	Aug. 18	7	4	Aug. 22	4	4	Aug. 26	4	4	12	Sept. 14	1	.....	19	31
												Sept. 15	2	1	20	32
					Aug. 23	3	5	Aug. 27	3	4	13	Sept. 15	.....	1	19	32
												Sept. 16	1	1	20	33
		Aug. 19	7	5	Aug. 23	7	4	Aug. 27	3	4	13	Sept. 15	1	1	19	32
												Sept. 16	.....	1	20	33
								Aug. 28	2	5	14	Sept. 16	1	1	19	33
								Aug. 29	2	6	15	Sept. 16	.....	2	18	33
22	Aug. 16	Aug. 21	2	5	Aug. 25	1	4	Aug. 30	1	5	14	Sept. 16	.....	1	17	31
					Aug. 26	1	5	Sept. 3	1	8	18	Sept. 18	.....	1	15	33
23	Aug. 17	Aug. 23	1	6	Aug. 28	1	5	Sept. 4	1	7	18	Sept. 18	.....	1	14	32
		Aug. 24	1	7	Aug. 28	1	4	Sept. 4	1	7	18	Sept. 18	1	.....	14	32
24	Aug. 18	Aug. 24	1	6	Aug. 29	1	5	Sept. 5	1	7	18	.....	.....	.....	.....	.....
Totals and weighted averages.....			242	4.83	.....	268	3.58	.....	349	4.12	12.33	.....	282	281	22.36	[1] 33.76

[1] Average period for 111 males and 107 females.

The proportion of sexes under natural conditions was not determined, but among those reared in the life-history cages the males and females appeared in almost exactly equal numbers, there being 282 males and 281 females.

SEASONAL-HISTORY SUMMARY.

The cherry leaf-beetle hibernates in the adult stage. The beetles emerge from their winter quarters in the late spring, and, after feeding for a few weeks and mating, the females go to the bases of the trees and deposit their eggs in the accumulation of rubbish. In something less than two weeks the eggs hatch. The larvæ grow rapidly and in less than two weeks attain full growth, when they burrow a short distance into the ground, pass through their pupal stage, and, in from two to three weeks after entering the ground, reappear as adult beetles. These beetles feed until cold weather compels them to seek shelter for the winter.

The season of 1915 was unusually cold and wet, and this condition undoubtedly delayed the development of the insect to a considerable extent. The hibernating beetles appeared at North East on June 7. Within two weeks their numbers were noticeably diminishing, but beetles of both sexes were observed as late as August 5, and females collected at this time still contained eggs. Unfortunately the natural food plant and egg-laying habits were not learned until the 3d of August, but at this time many eggs were still unhatched. Larvæ continued to emerge until August 14, and from another lot of eggs collected August 5 larvæ were hatched as late as August 18. At the time these eggs were collected there were full-grown larvæ on the trees, and many had undoubtedly entered the ground for pupation. Larvæ were observed on the pin cherry as late as September 10, when a full-grown larva and a young third-stage larva were found on some foliage that had been brought into the laboratory two days earlier. The active feeding portion of the larval life in the cages varied from 10 to 20 days, the average being 12.33 days.

The period spent in the ground in the cages varied from 14 to 28 days, the average being 22.36 days. The total developmental period is from 45 to 50 days.

The earliest adult to emerge in the cages appeared on August 23, but the pale, newly emerged beetles were observed in the open on the 16th. On August 31 the adults of the new brood were abundant on pin cherry, while many young beetles and pupæ and a few larvæ were found in soil and leaf mold under the bushes. On September 8 adults were abundant, but by September 23 they had begun to disappear, and no pupæ could be found in the ground, although a few newly emerged adults were observed.

A PREDATORY ENEMY.

In the leaf mold at the base of wild cherry trees, in which cherry leaf-beetles were transforming in great numbers, small carabid beetles with a striking color pattern of black and yellow were also abundant. These beetles were determined by Mr. E. A. Schwarz to be a large form of *Lebia ornata* Say. (Fig. 9.) In confinement these carabids would eat pupæ and callow adults voraciously. In attacking an adult Galerucella the carabid would tear off one elytron and then eat the soft body tissues. In confinement one Lebia killed four callow Galerucella adults in one night; only one was eaten, but the others all had the wings on one side torn off and were more or less mutilated otherwise. When pupæ were killed nothing was left but the pupal skin.

Several other carabids were found in places where the cherry leaf-beetle transforms, but none was found feeding upon it, nor could any of them be induced to do so in confinement.

FIG. 9.—*Lebia ornata*, a predatory enemy of the cherry leaf-beetle. Much enlarged. (Original.)

CONTROL.

PREVIOUS RECOMMENDATIONS.

There is no indication from entomological literature that any experiments to control this beetle have been conducted previous to 1915. Pettit (1898), Chittenden (1899), and O'Kane (1914) have recommended the use of Paris green and other arsenicals, doubtless basing their recommendations on their knowledge of related insects. Pettit (1898) recommended also the use of soap solution and kerosene emulsion, if spraying must be done on the trees when fruit is ripening.

EXPERIMENTS IN 1915.

When the cherry leaf-beetle appeared in the vicinity of North East, experimental spraying against the grape-berry moth was in progress at this station. Consequently no experimental work to control the beetle was undertaken until four days later, when the work in hand was finished. The effectiveness of poisoned sprays in these experiments was lessened somewhat by the fact that the beetles were feeding less heavily at the time of the application than they had been immediately after their arrival in this region.

All spraying experiments made against beetles of the spring migration were in two small orchards belonging to the late J. L. Spofford and M. D. Phillips, except some small cage experiments which were conducted in the insectary yard. These two orchards adjoined each other and were alike in so many ways that they were treated as

one orchard. The trees were 4 years old and of Early Richmond and Montmorency varieties. The former variety was used almost exclusively in the experiments.

Arsenate of Lead.

KILLING STRENGTH.

In order to determine the amount of poison necessary to kill the cherry leaf-beetle, trees were sprayed with various strengths of arsenate of lead on June 11. Two, 3, 4, 5, and 6 pounds were used to 50 gallons of water; one-half pound of lime was added to each of these mixtures. In addition mixtures at the rate of 3 pounds to 50 gallons and 5 pounds to 50 gallons, to which had been added 1½ gallons of molasses, were applied. To supplement the conclusions on the effect of the various mixtures drawn from observation of the beetles on the trees sprayed, about 100 beetles were confined in a bag on a branch of one tree sprayed by each of the different mixtures. No burning of foliage followed the application of any of the solutions used.

The various arsenate of lead and lime mixtures were ineffective in killing many of the beetles. The stronger solutions—4, 5, and 6 pounds to 50 gallons—were repellent and consequently to an extent protected the trees. The weaker solutions—2 and 3 pounds to 50 gallons—were ineffective even as repellents, for the beetles confined in bags on trees thus sprayed fed without apparent inconvenience. The beetles confined in bags on the trees sprayed with the stronger solutions, especially 5 and 6 pounds to 50 gallons, fed but little, although they were confined for a week. A negligible number of beetles, never 10 per cent, was found dead in the bags.

The sweetened arsenate of lead used at the rate of 3 pounds to 50 gallons was comparatively effective, although far from satisfactory. There were some dead beetles on the ground, and 40 per cent of those in the bag were dead. There was a good deal of feeding on the tree.

The sweetened arsenate of lead applied at the rate of 5 pounds to 50 gallons was effective. There were many dead beetles on the ground under the trees, and of the beetles in the bag 96 per cent were dead when examination was made three days after spraying. The trees sprayed with this mixture were effectively protected from injury.

On June 14 a tree that had been sprayed with 2 pounds of arsenate of lead to 50 gallons three days previous was resprayed with the same mixture to test the effectiveness of a double spray with a weak solution. The application was ineffective.

A second comparison of the sweetened and unsweetened mixtures of arsenate of lead was made June 19. The only strength of poison used was 5 pounds to 50 gallons of water, the weakest solution

effective in the first experiment. No lime was added to the unsweetened mixture and the molasses was used at the same rate as formerly, viz, 1½ gallons to 50 gallons of water.

Dead beetles were found under all the trees sprayed, but they were far more numerous under the trees sprayed with the sweetened mixture than under those sprayed with the unsweetened mixture. Also there was less feeding on the trees sprayed with the sweetened arsenate, although there was comparatively little on either, while the unsprayed check was loaded with beetles.

EFFECT OF LIME IN COMBINATION WITH ARSENATE OF LEAD.

To test the effect of lime as a repellent when used in sprays in combination with arsenate of lead, beetles were caged on parts of a tree in the insectary yard sprayed with lime water at the rate of 1 pound to 50 gallons and 5 pounds to 50 gallons. In both cages the beetles fed as freely on the leaves thus sprayed as on those that had not been sprayed.

Contact Sprays.

SOAP-CARBOLIC ACID SOLUTION.

A solution of fish-oil soap, 10 pounds to 50 gallons of water, to which three-fourths of a pint of carbolic acid was added, was tried as a contact spray on June 11. Immediately upon the application of this solution the majority of the beetles fell from the tree, apparently dead. Several hundred of these were gathered from the ground, placed in vials, and taken to the insectary. By the evening of the next day practically all of the beetles were active again and apparently uninjured by the spray. The solution is not permanently repellent, for the trees thus sprayed were badly attacked again two days after the application of the spray. This spray was not injurious to foliage.

NICOTINE SULPHATE.

A solution of 40 per cent nicotine sulphate at the rate of 1 part to 600 parts of water, to which was added fish-oil soap at the rate of 2 pounds to 50 gallons of liquid, was used as a contact spray on June 11. The effect was apparently similar to that of the soap-carbolic acid solution; some of the beetles escaped by flight but the majority fell from the tree when hit by the spray and soon appeared dead. Several hundred of them were gathered and taken to the insectary to test the permanence of this state. They were kept under observation for five days without showing any signs of life.

In order to compare the effectiveness of nicotine sulphate without soap, a large tree in the insectary yard was sprayed with nicotine

sulphate (40 per cent) on June 27. Of the beetles that fell from the tree, 318 were collected on a sheet and placed in a ventilated cage in the insectary. Five days later practically all of them, over 98 per cent, still showed no signs of life.

Weaker dilutions of 40 per cent nicotine sulphate were tested on September 9 on beetles of the new brood. Pin-cherry trees were sprayed, because at this time the beetles were feeding on no other. The following strengths were used: One part of nicotine sulphate to 800, 1,000, and 1,200 parts of water, respectively. Soap was added as in the first experiment at the rate of 2 pounds to 50 gallons of liquid. None of these strengths was effective, and none of them showed the immediate effects that followed spraying with a solution at the strength of 1 to 600. Many of the beetles hit with the sprays of the strengths of 1 to 800 and 1 to 1,000 became very sluggish and in 10 or 15 minutes appeared dead. Very few of those hit by the 1 to 1,200 solution appeared injured at all. About 150 beetles were collected from trees sprayed with each solution and placed in jars in the insectary. On the evening of September 10, 60 per cent of the beetles sprayed with the 1 to 800 solution, 68 per cent of those sprayed with the 1 to 1,000 solution, and 96 per cent of those sprayed with the 1 to 1,200 solution were active and feeding.

Results from Spraying by Growers.

Immediately following the advent of the cherry leaf-beetle in the Lake Erie grape belt there was unusual spraying activity to check it. Arsenate of lead was used in most instances, but applications of lime-sulphur, Bordeaux mixture, nicotine sulphate, soap, and lime, used in various combinations and at various strengths, were also made. The results were various.

Orchards in which arsenate of lead had been used at the rate of 5 pounds to 50 gallons of water, with and without lime, were observed by the writers. In these orchards the trees were generally quite well protected, although few dead beetles were found on the ground under the trees. Where weaker solutions of poison were used the results were far from satisfactory in the orchards observed. The use of sweetened arsenate of lead was observed in only one orchard outside of the experimental plats, and in this instance it was entirely unsuccessful. The spray was applied immediately before a heavy rain, which washed it all off.

A number of combination sprays in which 40 per cent nicotine sulphate was used were successful. The nicotine sulphate was sometimes used at rates as strong as 1 to 400. The following is a typical effective mixture: Arsenate of lead, 3 pounds; 40 per cent nicotine sulphate, 1 pound; laundry soap, 2 bars; water, 50 gallons.

Hydrated lime, dusted on trees by hand, was used as a protective measure, and in some instances appeared to be effective.

Summary of Experiments.

From the experiments and observations described, the following conclusions may be drawn:

Arsenate of lead must be used at a rate of not less than 5 pounds to 50 gallons of water to be effective in protecting trees from injury by the cherry leaf-beetle. A mixture to which molasses was added at the rate of 1½ gallons to 50 gallons of the mixture was effective in killing practically all of the beetles which fed upon the trees on which this mixture was applied. This addition of sweetening to the arsenate has the serious disadvantage of making the spray easily washed off by rains. Arsenate of lead used without molasses was less effective in protecting the trees, although it killed some beetles and it was to an extent repellent to them. Lime in the amount in which it is added to an arsenate-of-lead spray was not repellent.

Forty per cent nicotine sulphate applied with water at the rate of 1 to 600, with or without soap, was effective as a contact spray. Weaker dilutions of nicotine sulphate and soap-carbolic acid solutions, although apparently effective at the time of application, did not have a permanent effect.

CONTROL OF LARVÆ.

If the larvæ fed on a cultivated plant, control measures might be directed against it, thus preventing the adults from developing in destructive numbers. But it feeds on a wild plant that is usually present where control measures can not be applied, often on land that is in no way controlled by the fruit grower, and not even in the immediate vicinity of fruit farms. Nevertheless the clearing up of cut-over timberland and the destruction of the wild hosts of the larva of this beetle would greatly limit its possibilities of destructiveness. Should the cherry leaf-beetle become a permanent pest, cooperative work along this line might be advisable.

RECOMMENDATIONS.

Spray practice for the control of the cherry leaf-beetle at the time of its next appearance in economic numbers can not be absolutely determined from the foregoing experiments. The numbers of the beetles, the duration of the migration, and the weather conditions at the time must qualify any recommendation. More extensive experiments also might modify the results.

Nicotine sulphate, while temporarily effective, does not prevent a new invasion of an orchard on the day following its application. However, its use in peach orchards is recommended, for the greater

strengths of arsenate of lead would be likely to cause severe injury to peach foliage. The addition of 2 pounds of soft soap or 1 pound of hard soap to 50 gallons of the mixture has been generally found to increase the effectiveness of the nicotine sulphate.

Sweetened arsenate of lead is recommended for cherry trees because of its efficiency in killing the beetles and because its effect is continuous in favorable weather. Rain destroys the effectiveness of this spray. The combination found most useful is 5 pounds of arsenate of lead, 1½ gallons of molasses, and 50 gallons of water.

If the beetle migration should occur during a rainy period, the unsweetened arsenate of lead might be most useful.

In applying a poison spray care must be taken to cover the underside of the leaves where the beetles feed. In some instances it may be necessary to spray only young cherry trees or older trees of the thin-leaved varieties. In large orchards into which the beetles are migrating in great numbers it is advisable to spray first the trees most susceptible to attack, for during the season of 1915 the maximum injury occurred immediately after the first arrival of the beetles. In no case should the sweetened arsenate of lead be used with Bordeaux mixture as a combination spray, for burning of foliage is likely to result.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 358

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER April 12, 1916

STUDIES OF THE MEXICAN COTTON BOLL WEEVIL IN THE MISSISSIPPI VALLEY

By

R. W. HOWE, Entomological Assistant, Southern Field Crop Insect Investigations

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INTRODUCTION.

Shortly after 1892, when the Mexican cotton-boll weevil (*Anthonomus grandis* Boh.) invaded Texas on its northward and eastward journey and its extreme importance was seen, complete data were secured on the various biological functions. In recent years, however, numerous observations have shown that, under new climatic and other environmental conditions to which the weevil has been subjected in its spread, changes have been taking place in many of these functions. In addition, a new variety of the boll weevil has been found breeding in a wild cotton (*Thurberia thespesioides*) occurring in the mountain ranges of southeastern Arizona, and this weevil (which has been described as *Anthonomus grandis thurberiae* Pierce) has been found to possess habits which differ in many ways from those of its near relative on cultivated cotton. Consequently, it has been necessary to repeat many studies under both the old and the new conditions and to include the new variety. In this way the

NOTE.—This bulletin is of interest to entomologists in the cotton belt.

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extent and trend of the variations may be determined and a more definite knowledge of what to expect in the future may be obtained. As every phase of the control of the weevil is based upon biological facts, life-history studies have a very direct economic bearing upon the boll-weevil problem.

During 1913, 1914, and 1915 the writer conducted a number of studies on the biology of the weevil at the Delta Boll Weevil Laboratory at Tallulah,[1] La. The present paper deals largely with the results of these two years' observations, but before detailing these it is probably best to review very briefly the times and conditions under which the similar studies have been conducted.

The earliest work was that at Victoria, Tex., in 1902 and 1903, the results being published early in 1904.[2] This was followed by similar investigations at the same place during 1904, and the results of these studies were included in a bulletin issued in 1905.[3]

During 1910 similar investigations were conducted at Tallulah, La., and the results were published in 1911.[4]

Then, in 1912, these studies and such others as had been made elsewhere were brought together in a large bulletin issued in 1912.[5]

During 1913 another series of studies was conducted at Victoria, Tex., to check those which had been made at the same place 10 years earlier. It was found that the weevils had made a number of important changes in their life history, principal among these being a much greater adaptability to plants other than cotton as food. The biology of the Arizona Thurberia weevil was also studied, and this variety was hybridized with the Texas cotton weevils. The results of these studies are included in three papers.[6]

In 1914 the life history and habits of the Arizona weevil were studied under natural conditions in the mountains near Tucson, Ariz. These studies are discussed in two papers.[7]

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[1] The writer wishes to acknowledge his indebtedness to Mr. E. K. Bynum for assistance in the work of 1915.

[2] Hunter, W. D., and Hinds, W. E. The Mexican Cotton Boll Weevil. U. S. Dept. Agr. Bur. Ent. Bul. 45, 116 p., 16 pl., 6 fig., 1904.

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Thus it is seen that these studies embrace a wide range of time and conditions. In fact, the conditions of humidity, rainfall, temperature, altitude, soil, etc., include practically all extremes found in the cotton belt.

The various breeding series of 1914 and 1915 were conducted in a large insectary located at the Delta Laboratory, Delta, La. (fig. 1). This was provided with screen sides to furnish free air circulation, and the curtains were so arranged that the direct sunshine did not reach any of the breeding cages. Practically all of the breeding

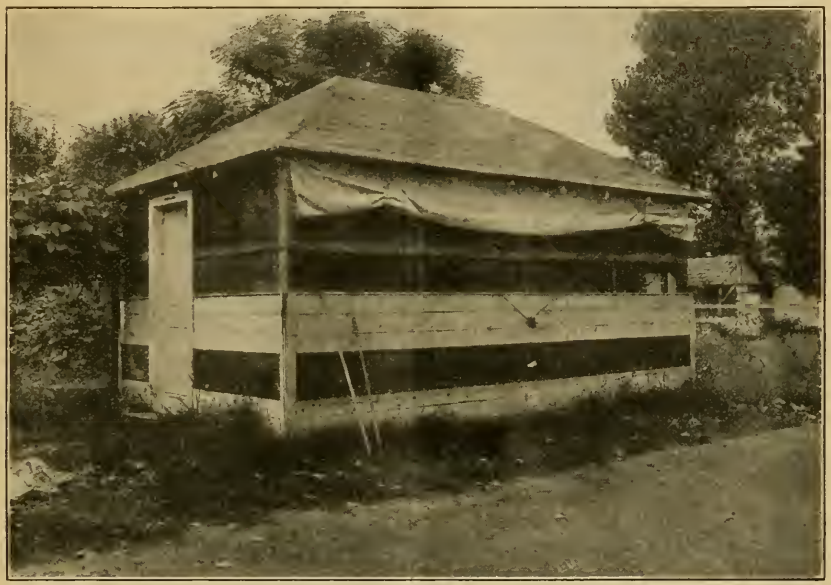

FIG. 1.—Insectary at the laboratory at Delta, La., for studies on the boll weevil. (Original.)

work was done in glass tumblers partially filled with moist sand and covered with a double thickness of cheesecloth.

LONGEVITY OF ADULT WEEVILS.

A considerable number of observations were made on the adult longevity on different foods. The data secured are separated by seasons.

SEASONS OF 1913 AND 1914.

Table I gives the observations made during the seasons of 1913 and 1914. The maximum record of longevity in 1914 was made by a first-generation female fed on cotton squares. This female emerged July 13 and died October 28, with a total life of 107 days. The maximum length of life of male weevils fed on cotton squares was 100 days; this individual emerging July 14 and dying October 22. The average longevity was 9.8 days on cotton leaves, 10.5 days on cotton bolls, and 46.3 days on cotton squares.

TABLE I.—*Duration of life of boll weevils. Observations of 1913–14.*

VARIETY GRANDIS WITHOUT NORMAL FOOD.

Season and period.	Food.	No. of weevils.	Weevil days.	Average longevity.	Maximum longevity.	Remarks.
1913.				*Days.*	*Days.*	
Sept. 24 to Oct 7....	Hibiscus leaves..	4	24	6.0	13	In paper bags on plants.
Sept. 24 to Oct. 10...	Hibiscus bolls...	4	25	6.3	16	Do.
Do.....	Hibiscus leaves, flowers, and bolls.	4	46	11.5	16	Do.
Sept. 24 to Oct. 9....	Okra buds and fruit.	8	44	5.5	15	Do.
Sept. 24 to Oct. 12...	Okra fruit.....	8	75	9.4	18.	Do.
Sept. 24 to Oct. 8....	Okra leaves.....	4	26	6.5	14	Do.
Sept. 24 to Oct. 10...	Thurberia leaves	4	42	10.5	16	Do.
Sept. 24 to Oct. 4....	Thurberia tips and buds.	4	34	8.5	10	Do.
Sept. 24 to Oct. 8....	Thurberia squares.	4	29	7.3	14	Do.
Total longevity on malvaceous plants..		44	345	7.8	18	

VARIETY GRANDIS WITH NORMAL FOOD.

1914.						
Aug. 6 to —.....	Cotton leaves....	40	390	9.8	17	In glass tumblers.
July 15 to Aug. 1....	Cotton bolls.....	20	210	10.5	16	Do.
June 3 to Oct. 28....	Cotton squares..	24	1,106	46	107	Females in glass tumblers.
June 13 to Oct. 28...	.....do.....	24	1,118	46.6	100	Males in glass tumblers.
Total on normal food.....		108	2,824	26.1	107	

In the abnormal food studies the weevils lived an average of 6 days on Hibiscus leaves; 11.5 days on Hibiscus leaves, flowers, and fruit; 6.25 days on Hibiscus tips; 6.5 days on okra leaves; 9.4 days on okra fruit; 11 days on okra leaves, flowers, and fruit; 10.5 days on Thurberia leaves; 8.5 days on Thurberia tips and buds, and 7.3 days on Thurberia squares. These records are all low, probably due to the experimental methods, as the weevils were all placed upon the food in paper bags and later observations show that the method apparently causes an early death.

SEASON OF 1915.

The studies of 1915 compare the longevity of *grandis* weevils on moist sand with no food, on moist sand with okra and Hibiscus, on moist sand with different parts of the cotton, and also *thurberiae*, on moist sand with okra, with cotton bolls, and with cotton squares. The species of Hibiscus used were *H. militaris* and *H. moscheutos*. The results are given in Table II.

TABLE II.—*Duration of life of boll weevils. Observations of 1915.*

VARIETY GRANDIS WITHOUT NORMAL FOOD.

Date.	Substance provided.	Males.				Females.				Both sexes.		Notes on weevils.
		Number.	Weevil days.	Average longevity.	Maximum longevity.	Number.	Weevil days.	Average longevity.	Maximum longevity.	Maximum longevity.	Average longevity.	
				Days.	*Dys*			*Days.*	*Dys*	*Dys*	*Days.*	
June 9	No food	54	148	2.77	40	9	36	4.0	15	40	2.9	Hibernated weevils.
June 8	do	30	162	5.4	10	30	167	5.57	11	11	5.48	Collected in field. Hibernated.
June 29	do	20	40	2.0	6	20	48	2.4	5	6	2.20	Bred.
Sept. 8	do	12	27	2.25	3	12	33	2.75	3	3	2.50	Do.
Aug. 13	do	20	63	3.15	10	20	69	3.45	10	10	3.30	Do.
Total without food		136	440	3.24	40	91	353	3.88	15	40	3.49	
July 2	Young okra fruit	6	22	3.67	6	6	27	4.5	7	7	4.1	Bred from squares collected in field.
July 22	do	11	48	4.36	12	10	39	3.9	5	12	4.1	Do.
Aug. 13	Okra bloom and bud.	9	72	8.0	11	9	44	4.9	12	12	6.4	Bred from squares and fed on blooms until Aug. 7.
Aug. 2	Okra fruit	10	75	7.5	17	10	75	7.5	14	17	7.5	Collected in field.
Aug. 13	do	8	60	7.5	15	8	55	6.9	12	15	7.2	Bred weevils.
Aug. 24–27	do	14	123	8.8	18	14	164	11.7	20	20	10.3	Field collected.
Sept. 9	do	12	131	10.9	39	12	155	12.9	20	39	11.9	Do.
July 28	Hibiscus leaves	7	36	.....	....	(1)	(1)	(1)	....	5	5.1	Collected in field. Not sexed. Not included in averages by sexes.
July 28	Hibiscus blooms	32	156	.....	....	....	.....	.....	....	12	4.9	Do.
Aug. 25												
July 28	Hibiscus buds	4	18	.....	....	....	.....	.....	....	5	4.5	Do.
Do	Hibiscus bolls	40	185	.....	....	...	.....	.....	....	9	4.6	Do.
Aug. 18												
Total on malvaceous plants other than cotton		70	531	7.6	39	69	559	8.1	20	39	6.7	

VARIETY GRANDIS WITH NORMAL FOOD.

May 15	Cotton leaves	57	540	9.47	40	38	401	10.55	27	40	9.91	Hibernated.
June 12												
June 7	do	40	269	6.73	17	40	259	6.25	15	17	6.60	Bred.
June 21												
Aug. 9	do	38	258	6.80	17	39	332	8.51	32	32	7.66	Do.
Sept. 17												
Total on cotton leaves		135	1,067	7.9	40	117	992	8.48	32	40	8.17	
June 3	Cotton terminals	28	468	16.70	43	28	627	22.40	42	43	19.55	Field collected; probably hibernated.
June 9												
July 8	do	14	232	16.60	32	15	282	18.80	43	43	17.72	Bred.
Aug. 11	do	13	142	10.90	31	11	159	14.50	31	31	12.54	Do.
Sept. 7	do	20	259	13.00	31	19	187	9.84	45	45	11.44	Do.
Total on cotton terminals		75	1,101	14.68	43	73	1,255	17.19	45	45	15.92	
June 23	Cotton bolls	17	345	20.3	75	17	723	42.53	82	82	31.41	Do.
July 24												
June 20	Cotton squares	11	729	66.27	83	13	762	58.62	81	83	62.13	Bred. First generation.
June 21												
July 16	do	5	197	39.40	57	5	167	33.30	59	59	46.40	Bred. Second generation.
Aug. 9												
Total on cotton squares		16	926	57.88	83	18	929	51.61	81	83	54.56	
Total all *grandis* on cotton		243	3,439	14.15	83	225	3,899	17.33	81	83	15.68	

TABLE II.—*Duration of life of boll weevils. Observations of 1915*—Continued.

VARIETY THURBERIAE.

Date.	Substance provided.	Males.				Females.				Both sexes.		Notes on weevils.
		Number.	Weevil days.	Average longevity.	Maximum longevity.	Number.	Weevil days.	Average longevity.	Maximum longevity.	Maximum longevity.	Average longevity.	
				Days.	*Dys*			*Days.*	*Dys*	*Dys*	*Days.*	
Aug. 30	Okra fruit	8	163	20.4	39	8	129	16.1	37	39	18.3	Removed from bolls collected in Arizona Mar. 1, 1915.
May 3	Cotton leaves	11	647	58.82	97	10	616	61.6	78	97	60.14	From Thurberia bolls collected in Arizona Mar. 1, 1915.
July 15	do	5	350	70.0	78							Do.
July 18–Sept. 29	First generation on squares.	16	1,136	71.0	104	19	1,269	66.8	89	104	68.7	Do.
July 17–Sept. 22	Second generation on squares	6	250	41.7	61	10	478	47.8	66	66	45.5	Do.
July 27–Sept. 29	On cotton bolls	10	531	53.1	73	9	392	43.6	73	73	48.6	Do.
Total all *thurberiae* on cotton		48	2,914	60.71	104	48	2,755	57.40	89	104	59.05	

[1] Weevils not sexed.

The *grandis* males averaged 3.24 days with no food; 7.6 days on okra and Hibiscus; 7.9 days on cotton leaves; 14.68 days on cotton terminals; 20.3 days on cotton bolls, and 57.88 days on cotton squares. The average longevity of male *grandis* on parts of the cotton plant was 14.15 days.

The *thurberiae* males averaged 20.4 days on okra fruit; 62.3 days on cotton leaves, 53.1 days on cotton bolls, and 63 days on cotton squares. The average longevity of *thurberiae* males on parts of the cotton plant was 60.71 days.

The *grandis* females averaged 3.88 days with no food; 8.1 days on okra and Hibiscus; 8.48 days on cotton leaves; 17.19 days on cotton terminals; 42.53 days on cotton bolls, and 51.61 days on cotton squares. The average longevity of female *grandis* on parts of the cotton plants was 17.33 days.

The *thurberiae* females averaged 16.1 days on okra fruit; 61.6 days on cotton leaves; 43.6 days on cotton bolls, and 60.2 days on cotton squares. The average of female *thurberiae* on parts of the cotton plant was 57.4 days.

A comparison of the longevity of the two varieties on okra fruit, cotton leaves, cotton bolls, and cotton squares is shown in Table III.

TABLE III.—*Comparative longevity of Anthonomus grandis and A. g. thurberiae.*

Food.	Average longevity of grandis.	Average longevity of thurberiae.
	Days.	*Days.*
Okra fruit	5.4	18.3
Cotton leaves	8.17	62.04
Cotton bolls	31.41	48.6
Cotton squares	54.56	61.4
Average longevity irrespective of food	14.13	53.2

The longevity of *thurberiae* is greater in every instance than that of *grandis*, and the average longevity irrespective of food is nearly forty days greater for the *thurberiae* weevils.

The maximum longevity obtained in the 1915 experiments is 104 days, this record being made by a male *thurberiae* feeding on cotton squares.

The maximum longevity with no food was 40 days; on okra and Hibiscus 39 days; on cotton leaves 97 days; on cotton bolls 82 days; on cotton terminals 45 days, and on cotton squares 104 days.

The comparison of the longevity by sexes is shown in Table IV. Here it is seen that in *grandis* the females exceeded the males on every food except cotton squares while in the *thurberiae* variety the males lived the longer in each case. The observations relating to *grandis* are in accord with the earlier records, which stated that the females exhibited greater hardihood on abnormal foods, but that the relation was reversed with normal food.

TABLE IV.—*Comparison of longevity of the boll weevil by sexes. Observations of 1915.*

Food.	Males.			Females.		
	Number.	Weevil days.	Longevity.	Number.	Weevil days.	Longevity.
VARIETY GRANDIS.						
			Days.			*Days.*
None	136	440	3.24	91	353	3.88
Malvaceous plants	70	531	7.60	69	559	8.10
Cotton leaves	135	1,067	7.90	117	992	8.48
Cotton terminals	75	1,101	14.68	73	1,255	17.19
Cotton bolls	17	345	20.30	17	723	42.53
Cotton squares	16	926	57.88	18	929	51.61
Total grandis	449	4,410	9.82	385	4,811	12.50
VARIETY THURBERIAE.						
Okra	8	163	20.4	8	129	16.1
Cotton leaves	16	997	62.3	10	616	61.6
Cotton bolls	10	531	53.1	9	392	43.6
Cotton squares	22	1,386	63.0	29	1,747	60.2
Total thurberiae	56	3,077	54 9	56	2,884	51.5

The longevity records of 1914 and 1915 added to those previously obtained show that 6,119 weevils fed on water averaged 9.9 days; 308 weevils fed on cotton averaged 8.6 days; 542 weevils fed on malvaceous plants averaged 9 days; 146 weevils fed on cotton foliage averaged 24.3 days and 534 weevils fed on cotton squares averaged 54.2 days. The most interesting features of the recent investigations on longevity are the greater adaptability of *grandis* for abnormal food plants and the very great longevity of *thurberiae* on any food. In view of this trend displayed by *grandis* and the adaptations which have already been made by *thurberiae* it seems reasonable to expect that *grandis* will continue to acquire greater hardihood when offered only abnormal foods.

Field cage studies.—For comparison with the laboratory tests of longevity, several experiments were conducted in field cages. Large cages covered with 16-mesh screen were placed over growing cotton plants and the first hibernated weevils found in the field in the spring were placed in them. Six cages in all were started on dates ranging from May 12 to June 19. These cages were watched for the cessation of weevil injury to the plants. However, the greater part of the new weevils died almost immediately after installation and the latest date on which a weevil was observed alive was July 22. It is apparent that the conditions are very abnormal in these cages, owing to the effect upon the light, temperature, humidity, etc. In fact, the plants themselves make a very abnormal growth when caged. A few observations were made during this period to determine the difference in temperature inside and outside these cages and they indicated a slightly higher daily maximum inside the cage than outside. The observations generally indicate that the conditions are very abnormal in these cages and that there is serious danger of error in drawing conclusions based only on such observations.

FOOD PLANTS OF THE WEEVIL.

During the early investigations on the boll weevil many attempts were made to find the weevils feeding or breeding on any plant other than cotton but they were uniformly unsuccessful. In fact, the first record of a cotton boll weevil feeding in nature on any plant other than cotton was in 1913, when one individual was found at Victoria, Tex., eating a bloom of *Hibiscus syriacus*. Observations since that time have shown a number of cases of the weevils feeding on plants closely related to cotton. The most important of these seem to be okra and the various wild species of Hibiscus.

Okra.—Okra is found very closely associated with cotton in many parts of the cotton belt. In fact, the plants are usually scattered through the cotton fields or are in the small garden patches adjoining cotton. Consequently there is a very good opportunity for the weevils to attack this plant.

During 1915 a number of okra plants were examined for weevils with the following results: On September 10 a few plants were examined at Inverness, Miss. Three open blooms were found and five boll weevils were in them, one blossom containing three. On September 29 and 30 a total of 122 okra plants were examined between Tallulah and Mound, La. These plants had 114 open blooms but the only weevil found was on the fruit. This individual was watched for about five minutes and in this time it made no attempt to feed.

Several additional records of the weevil on okra were made during the season on the plants growing at the laboratory and also in the field. Nearly all of these weevils were in the blooms and, where feeding was found, it was confined to the petals and stamens. No evidence of breeding in the buds or fruit in nature was secured.

Laboratory studies were also made upon the feeding in captivity and the possibility of breeding in the buds or fruit of okra. Sixty-nine pairs of weevils were mated on okra buds and small fruit and given only this food until death. Eleven eggs were deposited normally and three externally, but the larvæ failed to survive on this food. The weevils fed quite freely on these foods and also on okra blooms. In fact, the greatest amount of feeding was on the immature boll at the base of the bloom. Occasionally this small boll would be riddled with feeding punctures.

One cage test was conducted in the attempt to produce somewhat the conditions which would exist if cotton planting were suddenly stopped and only okra left for food. For this purpose a large cage was erected in the laboratory yard over a row of growing cotton plants and a row of okra (fig. 2). On August 27, 100 weevils, 50 males and 50 females, collected from cotton in the field were placed in the cage. Daily observations on the relative number of weevils on cotton and okra were made for 10 days. During this time 294 observations were made of weevils on cotton, while they were found on the okra only 16 times.

On September 6 the cotton plants were carefully removed from the cage and only the growing okra left for the weevils. On September 7 six weevils were feeding on the okra and on September 8 seven weevils were located, one feeding on a leaf and three feeding on the bloom. On September 9 three examinations were made and from 3 to 6 weevils, one of which was feeding on a bloom, were found on the okra each time. After that date the weevils were found on the okra only at irregular intervals and on September 19 no live weevils were found in the cage. At this time all the okra fruit was closely examined for egg punctures but none were found. However, to make sure that none were overlooked, all the fruit was placed on moist sand in a breeding cage and saved for some time, after which the contents were examined but no signs of larval work were found.

Hibiscus.—Two species of Hibiscus are found commonly around Tallulah, La., viz, *militaris* and *moscheutos*. One plant of *Hibiscus lasiocarpus* was found but does not seem to be common. *H. militaris* and *H. moscheutos* are found principally in low, moist places such as

FIG. 2.—One of the cages containing cotton and okra plants, Delta, La. Photographed at time of introduction of boll weevils. (Original.)

the bayou banks, in roadside ditches, and in swamp land, where they grow to considerable size and fruit throughout most of the summer. No weevils were found on these, but practically all of the plants noted were some distance from cotton.

One plant of *H. militaris* was transplanted to the laboratory yard and a number of adult weevils were found feeding in the blooms during the season. The feeding was apparently confined to the stamens and petals.

In addition to these field observations laboratory studies were conducted in an attempt to rear weevils in Hibiscus buds as was done at Victoria, Tex., in 1913. In connection with these attempts, some interesting feeding records were secured.

Thirty-two weevils that were fed with Hibiscus blooms only were noted to feed freely on the petals, and four cases of feeding on the immature boll at the base of the bloom were also noted.

Four weevils were fed on Hibiscus buds alone; they fed sparingly but deposited no eggs.

In an experiment where 127 weevils were placed in breeding jars with fresh Hibiscus fruits, considerable feeding was noted and 5 eggs were deposited, 4 externally and 1 normally. The eggs deposited externally were placed in incisions in the Hibiscus bolls and saved on moist sand, but later examinations of these bolls showed no sign of larval work.

Other plants.—On September 4 two weevils were found on the foliage of cultivated zinnia growing at the laboratory.

Early in the spring hibernated weevils were confined in breeding cages with blooms of violet, peach, pear, and osage-orange and left until death, but no sign of feeding was found.

While the weevils were not found breeding on the various malvaceous plants and the laboratory attempt to get them to do so gave negative results, the increasing adaptability of the weevil to them as food is quite evident.

FEEDING HABITS ON COTTON LEAVES AND TERMINALS.

In connection with the studies on the longevity of the weevils on cotton leaves and terminals as already reported, a number of interesting observations were made on the character and extent of the feeding. Normally the weevils apparently never feed upon the leaves, and the feeding on the terminals is largely limited to the time before the first squares appear in the spring.

Cotton leaves.—Eighty pairs of weevils were placed in breeding cages on cotton leaves during the season and observations were made on a total of 747 weevil days. During this time the weevils fed 128 days on the leaf tissue alone, 30 days on the stem alone, and 211 days on both stem and leaf tissue; in other words, 34.7 per cent of the feeding was on leaf tissue, 8.1 per cent on stem, and 57.2 per cent on both leaf and stem. The feeding of *grandis* on the leaf tissue usually consisted of a limited number of small punctures but that of *thurberiae* was much more voracious. The latter would frequently devour almost the entire leaf in a day.

Cotton terminals.—Seventy-five pairs of weevils were fed on cotton terminals during the season and observations were made on a total of 1,920 weevil days. Feeding was observed on 1,226 weevil days. On 616 days the weevils fed on the stem alone, or 50.2 per cent of all feeding was on this part. On 602 days, or 49.1 per cent of the feeding days, the feeding was on both the stem and bud, while the bud alone was attacked on only 8 days, or 0.7 per cent of the feeding days.

The preference of the weevil for the stem in these two series was quite marked. This may be due to the mechanical stimulus presented by the shape of the stem which will allow punctures more or less like those made in the squares and bolls.

TABLE V.—*Relative proportions of the sexes of boll weevils. Observations of 1915.*

Variety and description of material.	Male.		Female.	
	Number.	Per cent.	Number.	Per cent.
Grandis:				
Hibernated weevils	439	55.00	360	45.00
Bred weevils	1,591	51.59	1,493	48.41
Total *grandis*	2,030	52.28	1,853	47.72
Thurberiae.				
Bred from cotton squares	71	55.98	56	44.02
Bred from cotton bolls	4	40.00	6	60.00
Total *thurberiae*	75	54.74	62	45.26
Hybrids:				
Male *thurberiae* and female *grandis*	52	50.49	51	49.51
Male *grandis* and female *thurberiae*	50	44.25	63	55.75
Total hybrids	102	47.22	114	52.78
Total and average of all weevils	2,207	52.10	2,029	47.90

SEX OF ADULTS.

A considerable number of the weevils handled during the season were sexed, and Table V shows the ratio of the sexes.

Of the hibernated *grandis* material, 439 were males and 360 were females, or 55 per cent males and 45 per cent females. Of the *thurberiae* weevils extracted from Thurberia bolls, 54.74 per cent were males and 45.26 per cent were females. Of the 214 sexed hybrid weevils bred during the season 47.22 per cent were males and 52.78 per cent were females. These last figures are in accordance with the observations in 1913 that there was a larger percentage of females in variety *thurberiae* and the hybrids than in the variety *grandis*.

PERIOD FROM EMERGENCE TO OVIPOSITION.

In the series of typical *grandis* females the period from emergence to oviposition when fed on squares varied from 2 to 16 days with an average of 6.6 days. Fourteen females emerging in late June averaged 5.9 days from emergence to oviposition and 5 females emerging in late July and early August averaged 8.8 days from emergence to oviposition. Thus it is shown that temperature has a

direct influence on the length of time elapsing between emergence and oviposition. Ten typical *thurberiae* emerging in late July and early August averaged 6.8 days from emergence to oviposition. These periods ranged from 3 to 10 days. *Grandis* females in Texas in 1913 averaged 6.1 days and *thurberiae* females 4 days. At Tallulah in 1910, 34 females averaged 6.35 days before oviposition.

PERIOD FROM FIRST FEEDING ON SQUARES TO OVIPOSITION.

The period from first feeding on squares after emergence from hibernation to egg deposition was observed only with typical *thurberiae* females and with crosses of *grandis* and *thurberiae*. With typical *thurberiae* emerging in June it ranged from 10 to 18 days with an average of 13.3 days, while male *thurberiae* mated with female *grandis* varied from 3 to 10 days with an average of 7 days. With female *thurberiae* mated with male *grandis* the period varied from 9 to 18 days with an average of 12 days. Female *thurberiae* mated with male *grandis* in Texas in 1913 averaged 13.5 days in May and June and 3 days in early September, while hibernated *grandis* males averaged 4.2 days in early May. These records seem to indicate that the period is several days longer for *thurberiae* than for *grandis*.

FECUNDITY.

In connection with the various breeding series conducted during 1915 a considerable amount of information on the fecundity of the females of various types was secured.

Fecundity of hibernated grandis females.—Questions have frequently been raised concerning whether or not it is necessary for a female to be fertilized in the fall to pass the winter safely and also as to whether or not it is necessary for the females to be fertilized in the spring before deposition can start. Two series of females were tested to determine their exact condition upon emergence from hibernation in the spring. One series consisted of isolated females which were collected immediately after emergence started and which were not offered an opportunity for copulation after that time, while in the other series males were left with the females throughout their life. Of course there is a possibility that some of these females may have been fertilized during the time between emergence and collection but this is very slight as the emergence had just started and they had had very little time in which to copulate. Earlier studies have shown that either square or boll food is necessary before the female can be successfully fertilized and there were extremely few squares present in the field before the time of collection of these weevils, consequently it seems safe to assume that at least the majority of these females had not been fertilized in the spring. Both series were given cotton squares for food and oviposition.

TABLE VI.—*Fecundity of hibernated females of Anthonomus grandis kept with males constantly during life.*

Activity of individual females.											Progeny produced by individual females.									
Date female collected.	Date oviposition began.	Date oviposition ended.	Oviposition period.	Eggs deposited.					Date male dead.	Date female dead.	Period last egg to death of female.	Male weevils bred.	Male weevil days.	Male developmental period.	Female weevils bred.	Female weevil days.	Female developmental period.	Total weevils bred.	Total weevil days.	Period both sexes.	Per centage eggs producing adults.
				Normally.	Externally.	Total.	Average per day.	Maximum per day.													
			Dys.								*Days.*			*Days.*			*Days.*			*Days.*	
May 26	June 3	Aug. 3	62	123	0	123	2.0	9	July 4	Aug. 3	0	9	121	13.4	13	176	13.5	22	297	13.5	17.89
Do.	June 1	June 9	9	5	0	5	6	4	July 14	June 9	0	1	14	14.0	1	14	14	2	28	14	40.00
Do.	June 2	June 26	25	63	0	63	2.5	5	July 14	July 5	9	2	29	14.5	7	105	15	9	134	14.9	14.29
Do.	June 6	June 29	24	26	0	26	1.1	4	July 24[1]	June 30	1	1	13	13	1	13	13	2	26	13	7.69
Do.	June 1	July 5	35	40	0	40	1.1	6	July 16	July 9	4	3	48	16	2	32	16	5	80	16	12.50
Do.	June 6	June 28	23	41	0	41	1.8	4	July 7	July 2	4	1	14	14	3	43	14.3	4	57	14.25	9.76
Do.	June 2	June 18	17	19	0	19	1.1	3	July 3[1]	June 22	4	0	0	.....	2	29	14.5	2	29	14.5	10.53
Do.	June 3	July 19	47	107	0	107	2.3	7	July 14	July 22	3	11	163	14.8	10	140	14	21	303	14.4	19.63
Do.	June 2	July 10	39	93	0	93	2.4	9	June 15	July 13	3	8	119	14.9	2	27	14.5	10	146	14.6	10.75
Do.	June 22	July 12	21	1	1	2	.1	1	June 8	July 24	12	1	17	17	0	0	.....	1	17	17	50.00
Do.	June 25	July 8	34	108	0	108	3.2	6	July 17	July 10	2	5	71	14.2	6	83	13.8	11	154	14	10.19
Do.	June 4	July 31	58	98	0	98	1.7	7	July 26	Aug. 2	2	5	72	14.4	12	168	14	17	240	14.1	17.35
Do.	June 2	June 23	22	19	0	19	.9	3	June 3[1]	June 28	5	3	44	14.7	1	12	12	4	56	14	21.05
June 16	June 17	July 31	45	105	0	105	2.3	7	Sept. 3	Aug. 6	6	5	78	15.6	3	44	14.7	8	122	15.25	7.62
June 17	June 20	Aug. 23	65	32	4	36	.6	5	June 21	Sept. 5	13	5	69	13.8	3	39	13	8	108	13.5	22.22
Do.	June 18	July 18	31	73	0	73	2.4	7	July 6[1]	July 24	6	6	81	13.5	4	56	14	10	137	13.7	13.70
Do.	June 18	July 14	27	150	1	151	5.6	12	Aug. 31	July 17	3	8	119	14.9	3	39	13	11	158	14.4	7.28
Do.	June 20	June 20	1	1	1	2	1	1	June 27	June 21	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	0
Do.	June 18	Aug. 4	48	128	1	129	2.7	8	Aug. 27	Aug. 8	4	10	132	13.2	12	155	12.9	22	287	13	17.05
Do.	June 19	Aug. 5	48	156	1	157	3.3	7	June 30[1]	Aug. 9	4	13	179	13.8	20	268	13.4	33	447	13.5	21.02
Total			681	1,388	9	1,397	.....	115	.....	.....	86	97	1,383	.....	105	1,443	.....	202	2,826	.....	.....
Average			34.5	69.4	.45	69.85	2.05	5.75	.....	.....	4	.....	.....	14.3	.....	.....	13.7	.....	.....	14.0	14.46
Maximum			65	156	4	157	5.6	12	.....	.....	13	13	.....	17.0	20	.....	16.0	33	.....	17.0	50.0
Minimum			1	1	.....	2	.6	.....	.....	.....	1	.....	.....	13.0	0	.....	12.0	0	.....	13.0	0

[1] Escaped.

Latest date of deposition, August 23. Average date of cessation of oviposition, July 13.

TABLE VII.—*Fecundity of hibernated females of Anthonomus grandis not fertilized in spring.*

Activity of individual females.										Progeny produced by individual females.									
Date female collected.	Date oviposition began.	Date oviposition ended.	Oviposition period.	Eggs deposited.					Date female dead.	Period last egg to death of female.	Male weevils bred.	Male weevil days.	Male developmental period.	Female weevils bred.	Female weevil days.	Female developmental period.	Total weevils bred.	Total weevil days.	Period both sexes.	Percentage eggs producing adults.
				Normally.	Externally.	Total.	Average per day.	Maximum per day.												
										Days.			*Days.*			*Days.*			*Days.*	
June 1	June 2	June 29	28	32	0	32	1.2	3	June 30[1]	.....	6	87	14.5	3	41	13.7	9	128	14.2	28.13
Do	do	July 10	39	26	1	27	.7	4	July 14	4	2	28	14	0	0	0	2	28	14	7.40
Do	June 7	Aug. 22	77	49	9	58	.8	5	Aug. 23	1	5	69	13.8	6	81	13.5	11	150	13.6	18.96
Do	June 9	July 19	41	114	0	114	2.8	6	July 21	2	8	107	13.4	11	150	13.6	19	284	15.0	16.67
Do	June 16	July 21	36	14	1	15	.4	2	July 22	1	0	0	0	1	12	12	1	12	12	6.67
Do	June 9	June 28	20	2	2	4	.2	2	June 30[1]	.....	0	0	0	1	17	17	1	17	17	25.00
Do	June 12	July 8	27	4	4	8	.3	2	July 14	6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Do	June 9	July 19	41	10	8	18	.4	3	July 29	10	1	11	11	0	0	0	1	11	11	5.56
Do	June 7	June 30	24	8	5	13	.5	2	July 13	13	1	14	14	0	0	0	1	14	14	7.69
Do	June 7	Aug. 4	59	6	11	17	.3	2	Aug. 5	1	1	16	16	1	16	16	2	32	16	11.76
Do	June 9	July 4	26	14	0	14	.5	3	July 15	11	1	15	15	2	29	14.5	3	44	14.7	21.43
Do	June 15	July 30	46	4	2	6	.1	2	Aug. 5	6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Do	June 15	Aug. 17	64	9	30	39	.6	3	Aug. 23	6	1	17	17	2	27	13.5	3	44	13.7	7.69
Do	June 7	July 17	41	127	2	129	3.1	7	July 26	9	8	116	14.5	14	184	13.1	22	300	13.6	13.05
June 2	June 11	July 15	35	39	1	40	.9	4	July 17	2	5	66	13.2	3	43	14.3	8	109	13.6	20.00
Do	June 26	Aug. 13	49	12	9	21	.4	2	Aug. 22	9	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Do	June 19	July 3	15	1	2	3	.2	1	July 12	9	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Do	June 10	Aug. 23	75	31	16	47	.6	5	Aug. 25	2	3	40	13.3	1	16	16	4	56	14.0	8.51
Do	June 14	July 17	34	54	0	54	1.6	5	July 20	3	6	78	13	3	39	13	9	117	13.0	16.67
Do	June 9	June 26	18	35	1	36	2.0	5	June 26	0	3	48	16	3	42	14	6	90	15	16.67
Do	June 10	Aug. 20	72	85	13	98	1.4	6	Aug. 25	5	6	78	13	9	129	14.3	15	207	13.8	15.31
Do	June 15	July 22	38	59	6	65	1.7	5	July 24	2	13	179	13.8	10	134	13.4	23	303	13.2	35.38
Do	June 10	July 24	45	72	2	74	1.6	5	July 31	7	8	111	13.9	7	96	13.7	15	207	13.8	20.27
Do	June 12	July 3	22	43	0	43	2.0	3	July 9	6	5	73	14.6	2	28	14	7	101	14.4	16.28
Do	June 10	July 7	28	57	0	57	2.0	5	July 11	4	8	111	13.9	8	109	13.6	16	220	13.75	28.07
Total			1,000	907	125	1,032	.....	92	.....	122	91	1,264	.....	87	1,193	.....	178	2,457	.....	.....
Average			40	36.28	5	41.28	1.03	3.68	.....	5.3	.....	.....	13.9	.....	.....	13.7	.....	.....	13.8	17.25
Maximum			77	127	30	129	3.1	7	.....	13	13	.....	17.0	14	.....	17.0	23	.....	17.0	35.38
Minimum			15	1	0	3	.1	1	.....	0	0	.....	11.0	0	.....	12.0	0	.....	11.0	.....

[1] Escaped,

Latest date of deposition, August 23. Average date of cessation of oviposition, July 20.

From the results of these two series, shown in Tables VI and VII, it develops that all of the 25 isolated females deposited eggs, although 4 of them deposited less than 10 eggs each, whereas of the 20 fertilized females only 3 individuals deposited less than 10 eggs. The average oviposition period was 34.5 days for the isolated females and 40 days for females with the males. The average eggs for the isolated females was 41.2 with a maximum of 129, while for the females with males the average was 69.8 with a maximum of 157. However, it is seen that the isolated females averaged 5 eggs deposited externally while the females with males averaged only 0.45. Earlier studies have shown that practically all eggs deposited externally are infertile, which would indicate a lack of fertility on the part of isolated females. The average eggs per day for the isolated females ranged from 0.1 to 3.1 with a general average of 1.03, whereas for the females with males it ranged from 0.6 to 5.6 with an average of 2.05 eggs, thus proving the greater fecundity of the females with males.

The latest date of cessation of oviposition, August 23, was the same in both series, but the average date for the isolated females was 7 days later than that of the females with males. All eggs secured in both series were retained and as many adults as possible were reared. It is seen that 17.25 per cent of the eggs from the isolated females produced adults, while 14.46 per cent of those from the females with males produced adults. However, the eggs from every female in the series with males produced some adults, while those from 4 females in the isolated series failed to produce any.

From these observations it seems quite evident that at least a very high percentage of the females emerging in the spring are more or less fertile, but that their fecundity is considerably increased by later copulations.

Fecundity of first-generation grandis females.—The weevils used in this series were the first weevils bred during the season of 1915, the earliest emerging June 20. Thirteen pairs were mated and placed with cotton squares. (Table VIII.)

TABLE VIII.—*Fecundity of first-generation females of Anthonomus grandis on cotton squares.*

Date female emerged.	Date oviposition began.	Date oviposition ended.	Oviposition period.	Eggs deposited.		
				Total.	Per day.	Maximum per day.
			Days.			
June 20	June 26	Sept. 7	74	198	2.5	8
Do	...do	Aug. 4	40	197	4.93	10
Do	June 29	Aug. 29	62	91	1.5	7
Do	June 28	July 28	31	57	1.8	5
June 21	June 26	July 20	25	89	3.7	9
Do	...do	July 14	19	66	3.5	11
Do	June 23	Aug. 15	54	191	3.5	8
Do	June 27	Aug. 25	66	160	2.4	8
Do	...do	Aug. 27	62	142	2.3	12
Do	June 28	Aug. 31	65	107	1.6	6
Do	June 26	Aug. 26	62	111	1.8	6
Do	...do	July 28	33	110	3.3	7
Do	...do	Aug. 23	59	204	3.5	10
Total			650	1,723		
Average			50	132.5	2.7	
Maximum			74	204	4.9	12
Minimum			19	57	1.5	5

The total number of eggs deposited by each female ranged from 57 to 204 with an average of 132.5. The average number of eggs per female per day was 2.7 and the maximum was 12. The oviposition period varied from 19 to 74 days with an average of 50 days.

Fecundity of second generation grandis females.—Five pairs of weevils emerging from the first generation series were mated and placed with cotton squares during the last of July and the first of August (Table IX.)

TABLE IX.—*Fecundity of second-generation females of Anthonomus grandis on cotton squares.*

Date female emerged.	Date oviposition began.	Date oviposition ended.	Oviposition period.	Eggs deposited.		
				Total.	Per day.	Maximum per day.
			Days.			
July 16	July 23	July 29	7	13	1.9	4
Aug. 13	Aug. 18	Sept. 4	18	42	2.3	6
July 16	July 27	...do	40	93	2.3	8
July 29	Aug. 2	Sept. 5	35	175	5.0	10
Aug. 9	Aug. 17	Aug. 28	13	24	1.6	6
Total			113	347		
Average			22.6	69.4	3.1	
Maximum			40	175	5.0	10
Minimum			7	13	1.6	4

The total number of eggs per female ranged from 13 to 175 with an average of 69.4. The number of eggs per female per day varied from 1.6 to 5.0 and the maximum number was 10. The oviposition period ranged from 7 to 40 days with an average of 22.6 days.

Fecundity of hibernated thurberiae females.—The weevils used in this series were hibernated individuals extracted from cells in Thurberia bolls collected in Arizona on March 1, 1915. Nineteen pairs were mated on cotton squares on June 18. (Table X.)

TABLE X.—*Fecundity of hibernated females of Anthonomus grandis thurberiae on cotton squares.*

Date installed.	Date oviposition began.	Date oviposition ended.	Oviposition period.	Eggs deposited.		
				Total.	Per day.	Maximum per day.
			Days.			
June 18	June 29	Aug. 8	41	46	1.1	4
Do	June 28	Aug. 2	36	82	2.3	6
Do	July 5	July 25	21	9	.4	3
Do	July 1	Aug. 7	38	109	2.9	7
Do	...do....	Sept. 4	66	90	1.4	4
Do	June 29	Aug. 16	49	49	1.0	4
Do	...do....	July 17	19	26	1.4	5
Do	June 28	Aug. 25	59	76	1.3	5
Do	July 3	Aug. 18	47	47	1.0	4
Do	...do....	July 29	27	54	2.0	4
Do	July 1	July 20	20	5	.25	2
Do	June 28	Sept. 9	74	58	.8	5
Do	July 1	Aug. 3	34	54	1.6	6
Do	July 2	Aug. 2	32	62	1.9	5
Do	July 1	Aug. 20	51	45	.9	5
Do	...do....	Aug. 27	58	57	1.0	5
Do	July 2	Aug. 14	54	69	1.3	6
Do	July 5	Aug. 2	29	73	2.5	6
Do	June 29	Aug. 6	39	57	1.5	4
Total			794	1,068		
Average			41.79	56.2	1.3	
Maximum			74.00	109	2.9	7
Minimum			19.00	5	.25	

The total eggs per female ranged from 5 to 109, with an average of 56.2. The average eggs per female per day was 1.3, while the maximum was 7. The oviposition period varied from 19 to 74 days, with an average of 41.79 days.

Fecundity of first-generation thurberiae females.—Ten pairs of the progeny of the hibernated *thurberiae* reared in cotton squares were mated on cotton squares. (Table XI.)

TABLE XI.—*Fecundity of first-generation females of Anthonomus grandis thurberiae on cotton squares.*

Date installed.	Date oviposition began.	Date oviposition ended.	Oviposition period.	Eggs deposited.		
				Total.	Per day.	Maximum per day.
			Days.			
July 17	July 24	Sept. 1	40	72	1.8	5
July 18	July 28	Aug. 24	28	37	1.3	4
Do	July 24	Sept. 20	59	39	.7	5
Do	July 25	Sept. 9	47	15	.3	3
Do	July 25	Aug. 28	35	12	.3	3
Aug. 4	Aug. 10	Sept. 5	27	27	1.0	5
July 19	July 29	Sept. 22	25	11	.8	2
July 22	July 25	Aug. 3	10	7	.7	2
July 24	Aug. 3	Aug. 26	24	6	.3	2
Aug. 4	Aug. 7	Aug. 25	19	18	1.0	4
Total			314	244		
Average			31.4	24.4	1.4	
Maximum			59	72	1.8	5
Minimum			10	6	.3	

The number of eggs per female ranged from 6 to 72, with an average of 24.4, while the average per female per day was 1.4 and the maximum per day was 5. The oviposition period ranged from 10 to 59 days, with an average of 31.4 days.

From this and the preceding series the greatly reduced fecundity of *thurberiae* under the artificial condition prevailing at the Tallulah laboratory is quite evident.

Fecundity of bred grandis females mated with male thurberiae.—Late in June 12 newly emerged female *grandis* of the first generation were mated with hibernated male *thurberiae* on cotton squares. (Table XII.)

TABLE XII.—*Fecundity of bred females of Anthonomus grandis mated with male A. g. thurberiae on cotton squares.*

Date installed.	Date oviposition began.	Date oviposition ended.	Oviposition period.	Eggs deposited.		
				Total.	Per day.	Maximum per day.
			Days.			
June 22	June 29	July 7	9	35	3.9	7
July 27	Aug. 2	Sept. 8	38	134	3.5	9
June 22	July 2	July 28	27	124	4.6	8
July 27	Aug. 4	Aug. 31	28	19	.7	2
June 22	June 28	July 10	13	29	2.2	7
July 29[1]	Aug. 1	Aug. 28	28	100	3.6	8
June 22	June 28	July 7	10	31	3.1	5
July 27	Aug. 5	Sept. 10	37	87	2.4	6
June 22	June 30	July 13	14	32	2.3	5
July 27	Aug. 3	Sept. 19	48	87	1.8	6
June 22	June 28	July 3	6	13	2.2	6
Do	July 1	Aug. 7	38	113	3.0	7
Do	June 28	Aug. 10	44	166	3.8	15
Total			312	870		
Average			26	72.5	2.8	
Maximum			48	166	4.6	15
Minimum			6	13	.7	

[1] A complete record was not secured from this female owing to its escape on August 30, and consequently the figures are not included in the totals and averages.

The total eggs per female varied from 13 to 166, with an average of 72.5, and the average per female per day was 2.8. The oviposition period ranged from 6 to 48 days, with an average of 26 days.

The hybrid progeny reared from these eggs were mated on cotton squares and laid fertile eggs.

Fecundity of female thurberiae mated with male grandis.—In June 18 hibernated females of the variety *thurberiae* were mated with an equal number of male *grandis* on cotton squares. The detailed results are shown in Table XIII.

TABLE XIII.—*Fecundity of hibernated female Anthonomus grandis thurberiae mated with male A. grandis on cotton squares.*

Date installed.	Date oviposition began.	Date oviposition ended.	Oviposition period.	Eggs deposited.		
				Total.	Per day.	Maximum per day.
			Days.			
June 19	July 3	Sept. 7	67	31	0.5	3
Do	June 28	Sept. 3	68	77	1.1	4
Do	July 2	Aug. 13	43	133	3.1	8
Do	June 28	Aug. 6	40	48	1.2	5
Do	June 29	Sept. 2	66	72	1.1	4
Do	...do....	Aug. 3	36	65	1.8	5
Do	July 3	Aug. 4	33	47	1.4	4
Do	July 5	July 24	20	31	1.5	3
Do	June 30	Aug. 22	54	59	1.1	4
Do	July 7	Aug. 21	45	40	.9	4
Do	July 5	Aug. 20	47	51	1.1	4
Do	July 2	July 28	27	30	1.1	4
Do	June 28	Aug. 2	36	77	2.2	6
Do	...do....	Aug. 11	45	71	1.6	5
Do	July 1	Aug. 24	55	47	.9	5
Do	July 4	Aug. 4	32	32	1.0	2
Do	June 28	Aug. 2	36	35	1.0	4
Do	...do....	July 24	27	24	.9	4
Total			777	970		
Average			43.2	54	1.3	
Maximum			68	133	3.1	8
Minimum			20	24	.5	

The total eggs per female ranged from 24 to 133, with an average of 54, and the general average per day was 1.3 eggs. The oviposition period varied from 20 to 68 days and averaged 43.2 days.

The progeny of this cross were also mated and produced fertile eggs.

Fecundity of bred grandis females on cotton bolls.—Eighteen pairs of bred *grandis* weevils were placed with cotton bolls and furnished only this food until death. Seven of these females died without depositing a single egg. The activities of the remaining 11 are shown in Table XIV.

TABLE XIV.—*Fecundity of bred females of Anthonomus grandis on cotton bolls.*

Date installed.	Oviposition.			Total eggs.	Eggs per day.	
	Started.	Ended.	Period.		Average.	Maximum.
			Days.			
July 9	July 18	Aug. 3	17	5	0.3	1
Do	July 19	July 25	6	3	.5	2
Do	July 14	Sept. 7	45	17	.4	2
Do	July 28	Aug. 22	26	13	.5	2
Do	July 16	Sept. 5	52	17	.3	2
Do	July 12	Sept. 10	61	24	.4	3
July 16	July 23	Aug. 7	16	5	.3	3
July 24	Aug. 7	Aug. 17	11	2	.2	1
Do	Aug. 6	Sept. 16	42	5	.01	2
Do	July 30	Aug. 17	19	2	.01	1
Do	July 26	Sept. 16	22	8	.4	2
Total			317	101		
Average			29	9	.3	
Maximum			61	24	.5	3
Minimum			6	2	.01	

The total eggs per female varied from 2 to 24, with an average of only 9, and the average per day was only 0.3. The oviposition period ranged from 6 to 61 days, with an average of 29 days.

These results indicate the great difficulty with which oviposition is performed when only bolls are offered for food, but at least a large percentage of the eggs deposited were fertile, as 20 adults were reared from them.

Fecundity of hibernated thurberiae females on cotton bolls.—Nine pairs of *thurberiae* weevils were extracted from their hibernation cells in Thurberia bolls on July 27 and placed with cotton bolls at once. They were offered only this food until death. The results are given in Table XV.

TABLE XV.—*Fecundity of hibernated Anthonomus grandis thurberiae on cotton bolls.*

Date installed.	Date oviposition began.	Date oviposition ended.	Oviposition period.	Eggs deposited—			Maximum per day.
				Normally.	Externally.	Total.	
			Days.				
July 27	Aug. 11	Sept. 18	39	1	62	63	7
Do	July 28	Sept. 5	41	1	1	2	1
Do	Aug. 15	Aug. 28	14	1	1	2	1
Do[1]	July 28	Aug. 20	24	6	8	14	3
July 27	Aug. 4	Aug. 18	15	2	5	7	2
Do	July 28	Sept. 24	59	1	2	3	.....
Do	Aug. 4	Aug. 16	13	4	1	5	2
Do	Aug. 18	Sept. 9	23	1	1	2	1
Do	July 30	July 30	1	.....	1	1	1
Total	.....	.....	204	11	74	85	.....
Average	.....	.....	25.5	1.3	9.3	10.6	.....
Maximum	.....	.....	59	4	62	63	7
Minimum	.....	.....	1	.....	1	1	.....

[1] This female escaped Aug. 20, and consequently is not included in the averages.

One of these females escaped, and consequently only eight are considered in the averages. These eight deposited a total of only 85 eggs, and 74, or 89.4 per cent of these were deposited externally. It is striking that every female that deposited any eggs laid one or more externally. This is positive evidence of the unsuitability of bolls as food for these weevils.

The average total eggs per female was 10.6 and the average number deposited normally was only 1.3. These eggs were fertile, however, as several adults were reared from them.

Fecundity of grandis females on cotton bolls and squares on alternate days.—In addition to the foregoing studies on the effect of cotton bolls on the deposition of females another series was conducted in which each female was offered squares and bolls on alternate days. These females were bred individuals, which were fed squares until normal deposition started. Consequently this series does not show the effect of the boll food upon the fecundity of the females, but

simply shows the relative effect of the bolls and squares upon the act of oviposition. Table XVI shows the activity of nine females treated in this manner.

TABLE XVI.—*Fecundity of females of Anthonomus grandis on cotton squares and cotton bolls on alternate days.*

Eggs deposited in squares.			Eggs deposited in bolls.		
Total.	Maximum per day.	Average per day.	Total.	Maximum per day.	Average per day.
10	2	0.36	16	2	0.58
21	8	1.28	6	2	.12
24	6	2.00	5	1	.50
21	9	5.26	6	3	1.50
5	3	.28	8	3	.46
40	11	2.42	19	3	1.16
25	7	1.36	16	5	.86
23	5	1.54	11	2	.74
4	3	.16	1	1	.12
37	11	1.42	21	4	.80
41	9	1.52	12	3	.68
251	11	1.21	121	5	.59

From this it is seen that the average eggs per female per day was 1.21 on cotton squares and 0.59 on bolls. Consequently the greater suitability of the square for deposition is quite evident.

Summary of all fecundity observations on cotton squares.—Table XVII gives a brief summary of the foregoing studies on fecundity when the females were with males throughout life and were fed cotton squares. Here it is seen that the three series containing *thurberiae* females gave the lowest average of total eggs per female, and that the first-generation *grandis* gave the highest. The average eggs per female in all series was 68.2 and the average per day was 1.8.

TABLE XVII.—*Fecundity of all boll weevils on cotton squares: Summary.*

Source.	Number females.	Average eggs per female.	Average oviposition period.	Eggs per day.	
				Average.	Maximum.
			Days.		
Hibernated *grandis*	20	69.85	34.5	2.1	12
First generation *grandis*	13	132.54	50	2.7	12
Second generation *grandis*	5	69.4	22.6	3.1	10
Hibernated *thurberiae*	19	56.2	41.79	1.3	7
First generation *thurberiae*	10	24.4	31.4	3.5	5
Female *grandis* and male *thurberiae*	12	72.5	26	2.8	15
Female *thurberiae* and male *grandis*	18	54	43.2	1.3	8
Total	97				
Average		68.2	37.7	1.8	

The averages are all surprisingly low, the lowest on record for a season for the boll weevil, in fact. In 1902 to 1904, at Victoria, Tex., the females averaged 89 eggs each at the rate of 2.8 per day, while at

the same place in 1913 they averaged 212 eggs each at the rate of 5.9 per day. That this year's low record is not due to the difference in localities is shown by the fact that at Tallulah in 1910 the weevils averaged 208 eggs per female, at the rate of 5.5 eggs per day. The low records of 1915 may have been due to the extremely hot, dry weather prevailing during the period when most of the observations were made.

OVIPOSITION PERIOD.

The oviposition period of 122 females was observed during 1915. The results are shown in Table XVIII.

TABLE XVIII.—*Oviposition period of the boll weevil on cotton squares.*

Source of weevils.	Season.	Number of females.	Period.		
			Maximum.	Minimum.	Average.
Hibernated *grandis*	May–June	20	65	1	34.5
Hibernated *grandis* unfertilized in spring.	June–August	25	77	15	40.0
First generation *grandis*	June–September	13	74	19	50.0
Second generation *grandis*	do	5	40	7	22.6
Hibernated *thurberiae*	do	19	74	19	41.79
First generation *thurberiae*	July–September	10	59	10	31.4
Male *thurberiae* and female *grandis*	June–September	12	48	6	26.0
Male *grandis* and female *thurberiae*	do	18	68	20	44.3
Total	May–September	122			
Weighted average					38.2
Maximum			77		
Minimum				1	

The table shows that the oviposition period ranged from 1 to 77 days, with an average of 38.2 days for all females. The first generation *grandis* had the longest average period and the second generation *grandis* the lowest. There is no great difference between the length of the oviposition periods of *grandis* and *thurberiae*.

A series of 8 *thurberiae* females on cotton bolls averaged 25.5 days, with a maximum of 59 days and a minimum of 1 day, while a series of 11 *grandis* females on cotton bolls averaged 29 days, with a maximum of 61 days and a minimum of 6 days.

Observations of 32 females on cotton squares at Tallulah in 1914 showed an average oviposition period of 34.4 days, a maximum period of 80 days and a minimum period of 10 days. The average oviposition at Tallulah in 1910 was 34.44 days, and the average period in Texas in 1913 was 35.8 days. All records of female oviposition periods average several days less than the 1915 record of 38.2 days at Tallulah. Thus it is seen that if there is any tendency toward a change in the length of the oviposition period of the weevil it is in the nature of an increase rather than a decrease.

RATE OF OVIPOSITION.

The rate of oviposition by thirds of the period is shown in Table XIX. From this it is seen that the general average eggs per female per day was the same in the first and second thirds, while in the last it was lower.

TABLE XIX.—*Rate of oviposition of the boll weevil obtained in all experiments.*[1]

Nature of weevils.	Number of females.	Season.	Rate of oviposition.					
			First third of period.		Second third of period.		Last third of period.	
			Total eggs.	Daily avg.	Total eggs.	Daily avg.	Total eggs.	Daily avg.
Hibernated *grandis*	19	May to Aug.	505	2.3	504	2.2	387	1.7
First generation *grandis*	13	June to Sept.	578	2.7	692	3.2	453	2.0
Second generation *grandis*	5	July to Sept.	152	4.2	122	3.3	77	1.9
First generation *thurberiae*	10	....do	133	1.3	65	.6	46	.4
Hibernated *thurberiae*	19	June to Sept.	407	1.6	379	1.4	282	1.0
Male *grandis* and female *thurberiae*	18	.... do	397	1.5	373	1.4	198	.8
Male *thurberiae* and female *grandis*	13	.... do	289	2.7	392	3.5	275	2.3
Total			2,461		2,527		1,718	
Average				2.1		2.1		1.4

[1] Owing to the fact that the oviposition periods were rarely exactly divisible by 3 it was frequently necessary to allow a difference of a day on one or more of the periods. For this reason the divisors used in computing the final average were slightly different, and consequently the same average per day was secured in the first and second period, though the total eggs were slightly higher in the second period.

MAXIMUM NUMBER OF EGGS PER DAY.

The maximum number of eggs deposited by a female in a day was 15, this number being deposited on July 17 by a *grandis* female fertilized by a *thurberiae* male. This maximum is much lower than the maxima of previous years. The maxima of the various series carried through this year varied from 5 to 15 eggs.

The record for maximum eggs per day was made at Tallulah in 1914 when a first generation female laid 27 eggs. The maximum number of eggs in a day before this time was 26, this record being made by a female at Victoria, Tex., in 1913.

PERIOD FROM DEPOSITION OF LAST EGG TO DEATH.

The number of days from the deposition of the last egg to the death of the female varied from 54 days to death on the same day as the last deposition. The average of the 120 weevils observed during the season was 5.8 days. Typical *grandis* averaged 4.4 days to death, the periods of the individuals varying from none to 13 days. Typical *thurberiae* averaged 9.7 days, the periods varying from none to 54. Female *grandis* mated with male *thurberiae* averaged 2.3 days, the periods varying from none to six, while female *thurberiae* mated with male *grandis* averaged 6.2 days, the period varying from none to 24 days.

This period in the 1914 studies varied from 22 days to death on the same day that the last egg was deposited, with an average of 3.4 days. Death on the last day of deposition was observed five times during the season.

ACTIVITY OF FEMALES IN DIFFERENT PARTS OF THE DAY.

Early in August, 1914, two tests were conducted to determine the egg-laying activity of the females during the different parts of the day. Nine actively depositing females were used in each test. The results are shown in Table XX.

TABLE XX.—*Periodic division of oviposition of boll weevils.*

Period.	Length of period.	Total eggs laid.	Percentage of total oviposition in each period.	Maximum temperature.
			Per cent.	° *F.*
FIRST TEST: AUGUST 4 AND 5.				
Dawn	5 a. m. to 9 a. m.	16	12.8	77
Morning	9 a. m. to 1 p. m.	47	37.6	86
Afternoon	1 p. m. to 5 p. m.	29	23.2	90
Evening	5 p. m. to 8 p. m.	23	18.4	85
Night	8 p. m. to 5 a. m.	10	8.0	75
SECOND TEST: AUGUST 7 AND 8.				
Dawn	5 a. m. to 9 a. m.	8	9.1	72
Morning	9 a. m. to 1 p. m.	27	30.7	81
Afternoon	1 p. m. to 5 p. m.	39	44.3	86
Evening	5 p. m. to 8 p. m.	10	11.4	80
Night	8 p. m. to 5 a. m.	4	4.5	75
SUMMARY: BOTH TESTS.				
Dawn	5 a. m. to 9 a. m.	24	11.3	77
Morning	9 a. m. to 1 p. m.	74	34.7	86
Afternoon	1 p. m. to 5 p. m.	68	31.9	90
Evening	5 p. m. to 8 p. m.	33	15.5	85
Night	8 p. m. to 5 a. m.	14	6.6	75

From this table it is seen that in the first test the greatest activity was exhibited in the morning period and the afternoon period ranked second, while in the second test the afternoon period was highest and the morning period was second. In both cases the night was the lowest of all.

The only other test of this sort which has been conducted was at Tallulah during 1910 when it was found that the afternoon period ranked first and the evening period was second. However, this test was conducted during July and the one this year was in August, so the results are not strictly comparable owing to differences in the light and temperature conditions during the various periods.

CESSATION OF OVIPOSITION BY HIBERNATED WEEVILS.

Observations on the date of cessation of oviposition were made with 45 hibernated females collected in the field early in the season and fed on cotton squares. As shown in Table XXI the dates ranged from June 9 to August 23 and the average date of cessation in both series was July 17. All the females excepting two laid eggs on June 20 or later and a majority laid eggs well along in July. Since these females were nearly all selected from the first to appear in the spring it is certain that the later emerged adults would continue to oviposit considerably longer in the fall. Thus the futility of late planting of cotton to escape boll weevil attack is seen.

TABLE XXI.—*Dates of cessation of oviposition of first hibernated females of the boll weevil.*

With males throughout life.		Females isolated from males in spring.		With males throughout life.		Females isolated from males in spring.	
Date collected.	Date stopped ovipositing.	Date collected.	Date stopped ovipositing.	Date collected.	Date stopped ovipositing.	Date collected.	Date stopped ovipositing.
May 26	Aug. 3	June 1	June 29	June 17	Aug. 23	..do....	July 15
Do	June 9	..do....	July 10	Do	July 18	..do....	Aug. 13
Do	June 26	..do....	Aug. 22	Do	July 14	..do....	July 3
Do	June 29	..do....	July 19	Do	June 20	..do....	Aug. 23
Do	July 5	..do....	July 21	Do	Aug. 4	..do....	July 17
Do	June 28	..do....	June 28	Do	Aug. 5	..do....	June 26
Do	June 18	..do....	July 8			..do....	Aug. 20
Do	July 19	..do....	July 19			..do....	July 22
Do	July 10	..do....	June 30			..do....	July 24
Do	July 12	..do....	Aug. 4			..do....	July 3
Do	July 8	..do....	July 4			..do....	July 7
Do	July 31	..do....	July 30	Earliest date stopped	June 9	.....	June 26
Do	June 23	..do....	Aug. 17	Latest date stopped	Aug. 23	.....	Aug. 23
June 17	July 31	..do....	July 17	Average date stopped	July 13	.....	July 20

TOTAL DEVELOPMENTAL PERIOD.

Observations of 1914.—The time required from egg deposition to adult emergence was observed with all weevils bred in the various series until September 5. The maximum developmental period of any weevil was 20 days and the minimum period was 11 days. The results are tabulated according to season and generation in Table XXII.

TABLE XXII.—*Total developmental period of the boll weevil: Observations of 1914.*

Nature of weevils.	Larval food.	Period of oviposition.	Number males bred.	Male weevil days.	Average period.	Number females bred.	Female weevil days.	Average period.	Total number bred.	Total weevil days.	Average period.
					Dys			*Days.*			*Days.*
First generation.	Cotton squares.	June 2–July 2	3	44	14.7	7	110	15.7	10	154	15.4
Second generation.	do	June 23–June 30.	2	31	15.5	3	45	15	5	76	15.2
Do	do	July 1–5	11	170	15.5	18	269	14.9	29	439	15.2
Do	do	July 8–12	14	200	14.3	16	230	14.4	30	430	14.3
Do	do	July 13–20	50	753	15.1	41	603	14.7	91	1,356	14.9
Do	do	July 21–31	104	1,475	14.1	92	1,303	14.2	196	2,778	14.2
Do	do	Aug. 1–5	40	598	15	34	509	15	74	1,107	15
Do	do	Aug. 6–11	33	495	15	25	375	15	58	870	15
Do	do	Aug. 12–31	16	245	15.3	26	384	14.8	42	629	15
Do	do	Sept. 1–15	5	72	14.5	15	232	15.5	20	304	15.2
Total			275	4,039	14.7	270	3,950	14.6	545	7,989	14.6+
Third generation	do	July 15–21	20	279	14	17	242	14.2	37	521	14.1
Do	do	July 22–26	21	305	14.5	30	436	14.5	51	741	14.5
Do	do	July 27–31	14	204	14.6	13	187	14.4	27	391	14.5
Do	do	Aug. 2–10	14	208	14.9	22	330	15	36	538	15
Do	do	Aug. 11–24	9	127	14.1	11	164	15	20	291	14.6
Total			78	1,123	14.4	93	1,359	14.6	171	2,482	14.5
Fourth generation.	do	Aug. 2–10	14	211	15.1	18	266	14.8	32	477	14.9
Do	do	Aug. 11–23	22	312	14.2	29	416	14.3	51	728	14.3
Total			36	523	14.5	47	682	14.5	83	1,205	14.5
Fifth generation.	do	Sept. 2–5	5	72	14.5	6	86	14.3	11	158	14.4
Total			397	5,801	14.6	423	6,187	14.6	820	11,988	14.6

During the entire season 397 males and 423 females were bred. The average developmental period for both sexes was 14.6 days. Weevils bred later than September required a much longer developmental period but no positive record was kept of these weevils.

Observations of 1915.—The total developmental periods of all weevils observed during 1915 is detailed in Table XXIII.

TABLE XXIII.—*Total developmental period of the boll weevil: Observations of 1915.*

GRANDIS WEEVILS.

Source of weevils.	Larval food.	Oviposition period.	Males.			Females.			Total number bred.	Total weevil days.	Average period.
			Number bred.	Weevil days.	Average period.	Number bred.	Weevil days.	Average period.			
					Dys.			*Dys.*			*Dys.*
Hibernated weevils	Cotton squares	June 1–Aug. 23	97	1,383	14.3	105	1,443	13.7	202	2,826	14
Do	do	June 2–Aug. 23	91	1,264	13.9	87	1,193	13.7	178	2,457	13.8
First generation	do	June 26–Sept. 7	44	629	14.3	54	739	13.7	98	1,368	14
Second generation	do	July 23–Sept. 5	6	93	15.5	9	131	14.6	15	224	14.9
Grandis bred weevils	Cotton bolls	July 12–Sept. 16.	7	115	16.4	13	209	16.1	20	324	16.2
Total			245	3,484	14.2	268	3,715	13.9	513	7,199	14

THURBERIAE WEEVILS.

Weevils extracted from bolls.	Cotton squares	June 28–Sept. 9	55	792	14.4	49	709	14.47	104	1,501	14.43
First generation	do	July 24–Sept. 20.	16	234	14.6	7	95	13.6	23	329	14.3
Extracted from bolls	Cotton bolls	July 28–Sept. 24.	4	57	14.3	6	97	16.3	10	154	15.4
Total			75	1,083	14.4	62	901	14.5	137	1,984	14.48

HYBRIDS.

Male *grandis* by female *thurberiae*.	Cotton squares	June 28–Sept. 7	50	689	13.78	63	827	13.13	113	1,516	13.42
Male *thurberiae* by female *grandis*.	do	June 28–Sept. 19.	52	726	14.0	51	719	14.1	103	1,445	14
Total of all varieties.		1915	422	5,982	14.2	444	6,162	13.9	866	12,124	14

The average total period for both sexes in both squares and bolls was 14 days. The developmental period in bolls is seen to be greater than in squares with both *grandis* and *thurberiae* weevils. In cotton bolls the *grandis* weevils averaged 16.2 days and the *thurberiae* weevils averaged 15.4 days.

The total developmental period for females is slightly shorter than for the males, which agrees with the observations at Victoria, Tex., in 1913. The average developmental period is apparently a day or more shorter at Tallulah than at Victoria in the same season. There seems to be no difference of note in the records for the various years.

In addition to these studies an experiment was conducted to determine the relative length of the developmental period in squares and bolls when the eggs were deposited by the same female. For this purpose 11 pairs of bred *grandis* were mated on cotton squares until they started normal deposition; then they were given squares and bolls on alternate days and the eggs deposited in them were saved for adult emergence. The comparison of the results is shown in Table XXIV.

TABLE XXIV.—*Comparative developmental period of the boll weevil in squares and bolls from eggs deposited by females offered these foods on alternate days.*

Total eggs deposited.	In cotton squares.										In cotton bolls.									
	Males.			Females.			Both sexes.				Total eggs deposited.	Males.			Females.			Both sexes.			
	Total bred.	Weevil days.	Developmental period.	Total bred.	Weevil days.	Developmental period.	Total bred.	Weevil days.	Average developmental period.	Percentage of eggs producing adults.		Total bred.	Weevil days.	Developmental period.	Total bred.	Weevil days.	Developmental period.	Total bred.	Weevil days.	Developmental period.	Percentage of eggs producing adults.
			Days.			*Days.*			*Days.*					*Days.*			*Days.*			*Days.*	
10	1	14	14				1	14	14	10	16										
22				3	43	14.3	3	43	14.3	13.6	6	1	16	16	1	17	17	2	33	16.5	33.3
24	4	56	14	1	21	21	5	77	15.4	20.8	5				2	31	15.5	2	31	15.5	40
32	3	44	14.7				3	44	14.7	9.4	6	3	55	18.3	3	54	18	6	109	18.2	100
5	1	16	16	1	15	15	2	31	15.5	40	8										
66	2	37	18.5	5	80	16	7	117	16.7	10.6	19	3	45	15	4	62	15.5	7	107	15.3	36.8
28	3	40	13.3	1	13	13	4	53	13.2	14.3	16	4	70	17.5	3	54	18	7	124	17.7	43.8
26				2	27	13.5	2	27	13.5	7.7	11	2	30	15	2	33	16.5	4	63	15.8	36.4
4											1										
40	3	38	12.7	2	29	14.5	5	67	13.4	12.5	21	1	16	16	4	70	17.5	5	86	17.2	23.8
41	2	39	19.5	2	27	13.5	4	66	16.5	9.8	12	4	67	16.8	3	49	16.3	7	116	16.6	58.3
Total, 298	19	284		17	255		36	539			121	18	299		22	370		40	669		
Average			15			15			15	12.1				16.6			16.8			16.7	33.1

Here it is seen that the weevils reared from squares averaged 15 days while those from bolls averaged 16.7 days. The comparative percentages of eggs producing adults are also interesting. Of those laid in squares, 12.1 per cent produced adults while 33.1 per cent of those in bolls produced adults. This is undoubtedly due to the fact that some of the squares were too small to feed the larvæ to maturity and also to the fact that when two or more eggs hatch in the same square the shortage of food usually results fatally to both. The greater deposition in the squares is very marked.

EFFECT OF SIZE OF SQUARE ON WEEVIL DEVELOPMENT.

In July, 1915, an experiment was conducted to determine the effect of the size of the cotton square on the weevil developmental period. An abundance of clean squares was placed in a large wire cage with fertile females and left for one day. The squares containing single eggs were separated into lots of 50 squares each; one lot being small squares, one medium-sized, and the third large. The small squares produced one weevil in 14 days, the medium-sized squares produced 20 weevils in an average of 14.1 days, and the large squares produced 18 weevils in an average of 14.5 days. While the number of weevils reared is too small to make the results conclusive, it seems that the length of the developmental period is directly proportional to the amount of food available. This appears quite probable in view of the fact that the developmental period is always considerably longer in cotton bolls than in cotton squares. The small squares seemed not to furnish sufficient food for the weevil development as only one weevil was able to reach maturity in the 50 tested.

GENERATIONS.

One series of weevils was carried through the season of 1914 to determine the maximum number of generations possible in cotton squares in one year. For starting the series hibernated females were collected immediately after emergence in the spring and placed with males on cotton squares. The first eggs of these females were saved and the progeny reared. The first adults to mature from these were mated and their first eggs secured. This procedure was followed through the season, and the results are shown in Table XXV. Between the first of June and the first of November these weevils were carried through seven generations, the first and only weevil of the seventh generation emerging November 1. This individual was very weak and died in a few days, but as the cold weather at this time had stopped all breeding in the field it was evident that the limit of the breeding season had been reached.

TABLE XXV.—*Number of generations of the boll weevil: Maximum series on squares.*

Generation.	Date.	Period from maturity to maturity.
		Days.
First generation:		
Eggs laid	June 1	
Generation mature	June 22	
Second generation:		
Eggs laid	June 23	
Generation mature	July 9	18
Third generation:		
Eggs laid	July 15	
Generation mature	July 28	20
Fourth generation:		
Eggs laid	Aug. 2	
Generation mature	Aug. 18	22
Fifth generation:		
Eggs laid	Sept. 2	
Generation mature	Sept. 17	31
Sixth generation:		
Eggs laid	Sept. 18	
Generation mature	Oct. 8	22
Seventh generation:		
Eggs laid	Oct. 13	
Generation mature	Nov. 1	24

At Victoria in 1913 the weevils were carried through the same procedure and the same number of generations secured. However, the first hibernated females at Victoria were secured over a month earlier than those at Tallulah and the breeding continued a few days longer in the fall. In other words, the generations were sufficiently shorter at Tallulah to allow the same number to be produced in more than a month less than at Victoria.

SUMMARY.

In northern Louisiana the average longevity of the boll weevil adults on cotton squares was 54.56 days; on bolls 31.41 days; on cotton leaves 8.17, and on okra fruit 5.4, the average for these different classes of foods being 14.13 days.

The females live somewhat longer than the males, there being an average of 12.5 days for females and 9.82 for males.

A number of weevils were found feeding in okra blooms in the field but attempts to cause them to breed in okra fruit in the laboratory were unsuccessful. A number of eggs were deposited but they failed to hatch.

The largest number of eggs deposited by the first generation weevils was 204, the average being 132. The daily maximum varied from 5 to 12. Second generation weevils showed somewhat less fecundity, the maximum oviposition being 175 eggs and the average 69.4.

The average period of oviposition was 38.2 days, the range being 1 to 77 days.

The greatest activity of the weevil in depositing eggs was found to be between the hours of 9 a. m. and 1 p. m., but certain numbers of eggs were deposited at all times of the day and during the night.

The average period from oviposition to the emergence of the adult was practically 14 days for each of the five generations.

Seven complete generations were developed at Tallulah during the season.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 363

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER. May 8, 1916.

THE PINK CORN-WORM: AN INSECT DESTRUCTIVE TO CORN IN THE CRIB.

By F. H. CHITTENDEN, *In Charge of Truck Crop and Stored Product Insect Investigations.*

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INTRODUCTION.

For nearly three-fourths of a century the larva of a small moth (*Batrachedra rileyi* Wals.), commonly known as the pink corn-worm (fig. 1), has been found in corn in the field and in store as well as in blasted cotton bolls. It was not, however, until the year 1914 that this species was recognized as a pest. During November and December of that year complaints were made of damage by the pink corn-worm to corn in cribs. The number of complaints was enormous and the damage in Mississippi was so widespread that much alarm was felt in infested districts. The correspondence, which will presently be quoted, shows plainly the extent of the insect's ravages as also the fear that entire crops

FIG. 1.—The pink corn-worm (*Batrachedra rileyi*): Full-grown larva, lateral view. Enlarged. (Original.)

NOTE.—This bulletin points out the increasing menace of this insect, which has never been considered a serious enemy of grain, but now assumes nearly the same importance as the Angoumois grain moth and is much more troublesome than the European grain moth. It also recommends methods of control. It will prove of interest to farmers in the region extending from South Carolina westward to central Texas, southward to southern Texas, and northward to Arkansas and Tennessee.

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of corn in the principal regions infested might be lost. While the insect confined its attacks largely to Mississippi, it was also observed in injurious numbers in Arkansas, Alabama, Texas, and Louisiana.

Singularly, the species was not described until the year 1882, when Lord Walsingham gave it the name of *Batrachedra rileyi*, but it now assumes nearly the same importance as the Angoumois grain moth [1] and is much more troublesome now than the European grain moth.[2] The species sufficiently resembles the latter to have been mistaken for it by Glover and others, and its work has been compared to that of the former. In reality it bears some resemblance to both species in appearance and habits.

The pink corn-worm was first brought to the writer's attention in ripening ears of corn from Texas in 1894 (Chittenden, 1897).[3] From the fact that the larvæ first seen were feeding on the husks and the species was not then identified as feeding naturally on the kernels of corn, it was for convenience called the corn-husk moth, and this name might have been retained had not the insect developed later into a destructive grain-feeding species. The names pink corn-worm, pink worm, and red corn-worm are now in general use in the South.

NATURE OF INJURY.

In material received from Baton Rouge, La., and Beeville, Tex., in 1895, the little rose-colored larvæ were noticed by the writer chiefly between the husks, which were fresh and succulent, and on these they were feeding. A few moths were afterwards reared from the husked ear. The Texas sending afforded a fair opportunity for the study of the work of the species. One undeveloped ear harbored numbers of the larvæ which had gnawed into every part of it from the outer husk to the dwarfed ear within.

The injured grains when examined individually have somewhat the appearance of being infested by the Indian-meal moth (*Plodia interpunctella* Hbn.) but not by the Angoumois grain moth. The larvæ evidently begin to feed on the grains while the latter are still "in the milk" or very soon afterwards, beginning at their insertion and working outward toward the crown. The embryo and surrounding parts are hollowed out and the seed envelope is often eaten away about the base or "tip" of the seed. An astonishing amount of frass is developed which is neither eaten a second time nor packed tightly within the kernel, as is evidently the case with the Angoumois moth larva, but the particles, being loosely joined by webbing, fill the interstices between the kernels. (Pl. I.) Usually a single larva inhabits a kernel but frequently the interior of a grain is completely devoured, so that the only part remaining is the thin outer integument inclosing a varying amount of accumulated frass. Doubtless this is the work

[1] *Sitotroga cerealella* Zell. [2] *Tinea granella* L. [3] See Bibliography, p. 19.

of more than one caterpillar. It will be noted that the caterpillar does not confine itself, as does the Angoumois moth, to the kernel or any part of it, but attacks seed, husk, and cob alike.

While no positive statement can be made as to the cause of the sudden increase of the pink corn-worm, it may, perhaps, be due to the fact that cotton is not cultivated on so large a scale or so universally as in the past, and possibly it may be due to the destruction of the bolls by plowing them under as a remedy against the boll weevil. These practices would naturally have the effect of driving the moths to deposit their eggs on corn, and this acquired taste of the larvæ might in time be transmitted to their descendants. There can be no doubt that when corn is left too long in the field the ears are more easily penetrated by the insects. Often, too, if they are permitted to remain there over long they become moist, and if stored in this condition injury by the pink corn-worm and other insects is greatly hastened. Still another practice favors the multiplication of the moth, namely, storing corn too long in the husk. The layers of husks just under the outer sheath are frequently badly eaten at about the middle, only the longitudinal veins being rejected. On one fully developed ear nearly every kernel was infested and the ear was so completely enveloped in frass and webbing as to be useless for any purpose. Every ear in which this species was found lodged had been first attacked by the corn-ear worm (*Heliothis obsoleta* Fab.). (Pl. I.)

DESCRIPTION.

THE MOTH.

Batrachedra rileyi belongs to the same lepidopterous superfamily [1] as the Angoumois and European grain moths, but to a different family.[2] From either of the others this species may be easily distinguished by its smaller size and by its remarkably slender hindwings and their correspondingly long fringes. The forewings are banded and feebly mottled with yellow, reddish-brown, and black. The antennæ are white, annulated with fuscous, and the legs are banded with fuscous. (See fig. 2.)

The wings measure, when expanded from tip to tip, a little less than half an inch (9–11 mm.).

The moths are very active on their feet and when at rest fold their forewings closely together with their tips "cocked up" after the manner of many other tineids and related moths.

Following is the original description by Walsingham:[3]

Head chestnut-brown; palpi widely divergent, whitish, with an oblique pale brown mark on each side near the end of the second joint, and two or three brownish

[1] Superfamily Tineina.

[2] Family Elachistidae.

[3] Walsingham, Lord.—Notes on Tineidae of North America. *In* Trans. Amer. Ent. Soc., v. 10, p. 198–199, 1882.

spots on the sides of the apical joint. Antennæ with white and fuscous annulations; the basal joint elongate, chestnut brown. Fore-wings chestnut-brown, slightly shaded with fuscous towards the costal margin; a whitish ochreous streak at the base of the dorsal margin, followed by two or three other smaller ones along the dorsal margin (in some specimens these are obsolete); above the dorsal margin are two oblique whitish ochreous streaks, the first before the middle, the second before the anal angle. A similar streak from the costal margin immediately before the apex is outwardly margined by a streak of black scales, the apex and apical margin being also black; there is also a faint fuscous streak running downwards through the cilia below the apex. On the cell are two elongate patches of black scales, one immediately before the middle of the wing, the other halfway between this and the base. Fringes grey, with a slight yellowish tinge. Hind wings pale greyish. Hind tibiæ greyish white, outwardly fuscous; hind tarsi whitish, with a wide fuscous band followed by two fuscous spots on their outer sides. Expanse 11 millim.

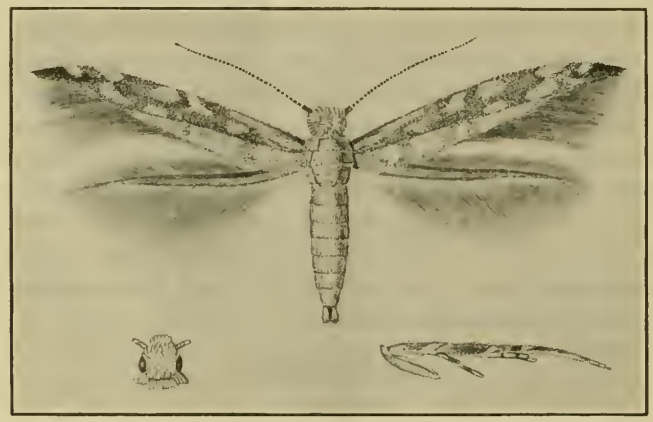


FIG. 2.—The pink corn-worm: Moth, showing head covered with scales; below, at left, head showing eyes at side; below, at right, hind leg. Moth much enlarged, head and leg more enlarged. (Original.)

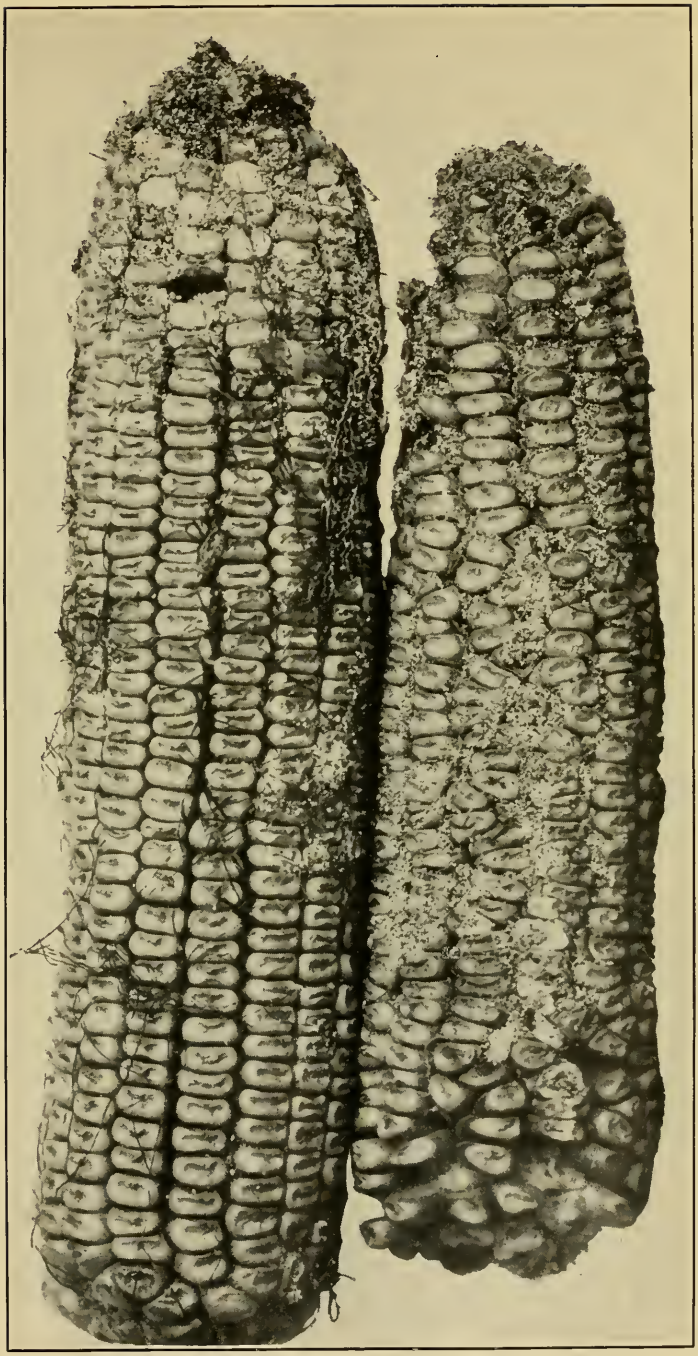
THE EGG.

The eggs of this species resemble considerably those of the Angoumois grain moth (*Sitotroga cerealella*). They have been found deposited on dry corn husks and in such locations are much flattened on the surface, differing in this respect from those of Sitotroga. The egg may be described as follows:

Flattened oval; widest near the middle; truncate at one end and narrowed at the other, with the surface strongly wrinkled, forming coarse, irregular, ridgelike longitudinal lines. As would naturally be expected in a species so much smaller than the Angoumois moth the egg is much smaller, and instead of being red it is pearly white throughout with a perceptible iridescence.

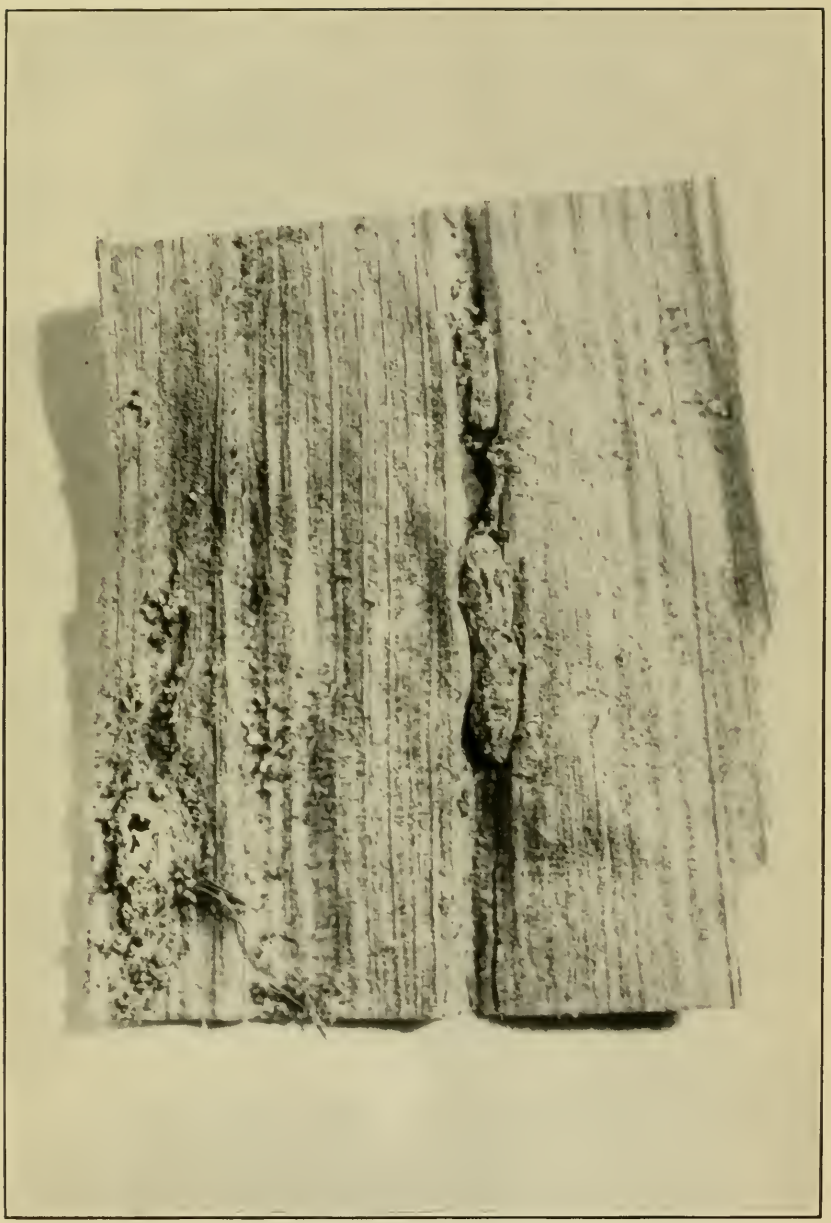
Measurement: Length, 0.4 mm.; width, 0.1 mm.

The eggs are deposited singly or in groups up to three or four. Since they are nearly colorless, not pinkish like those of the Angoumois moth, they are quite difficult to locate with the unaided eye. The egg is illustrated by figures 3 and 4.



WORK OF THE CORN-EAR WORM AND THE PINK CORN-WORM.

Corn ears showing primary injury by corn-ear worm (*Heliothis obsoleta*) at top and additional injury by pink corn-worm (*Batrachedra rileyi*), especially on right ear. (Original.)



COCOON OF THE PINK CORN-WORM ON SECTION OF DRY CORN HUSK, SHOWING A PUPA NEAR TOP AND TWO OVERLAPPING NEAR MIDDLE; ALSO LOCATION OF ONE OR TWO OTHERS AT LEFT. (ORIGINAL.)

THE YOUNG LARVA.

The larva when first hatched is nearly white, but soon becomes pinkish. The head and thoracic plate are darker. It is at this time about 1 mm. in length and quite slender.

FIG. 3.—The pink corn-worm: Eggs, highly magnified. (Original.)

THE FULL-GROWN LARVA.

When full grown the larva of this species bears some resemblance to that of the Indian-meal moth (*Plodia interpunctella*). It is, however, considerably smaller and more slender, and is somewhat flattened by comparison. It may be described as follows:

FIG. 4.—The pink corn-worm: Egg, highly magnified. (Original.)

When fully extended it is about eight times as long as wide. Head quite narrow, in contour nearly identical with that of Plodia; of the same pale brown color, with sutures well marked, and appendages and mouth-parts still darker. Thoracic plate nearly one-third wider than head, well divided at middle; light brown dorsally and dark brown at sides. Thorax and dorsum sparsely covered with concolorous piliferous tubercles with inconspicuous hairs. Body entirely pale carneous or pinkish; lower surface showing slight carneous tint in first two thoracic joints and along the sides. Anal plate quite small, about the same color as the head. Legs whitish and rather short. Prolegs consisting of five pairs. Length, 8 mm.; width, 1.2 mm.

The full-grown larva is illustrated in figures 1 and 5.

The arrangement or pattern of the pink color is shown in figure 5. It appears to be distinctive.

THE PUPA.

Somewhat robust, about three times as long as wide; head subtruncately rounded at apex; eyes large, black, passing under the basal joints of antennæ, showing plainly at the sides and from the back; wing-cases and antennal cases reaching nearly to penultimate segment; segments well-defined, last segment with rounded area near middle and terminating with several short, delicate bristles curved at extreme apices like minute hooks; color yellowish brown.

Length, about 4.5 mm.; width, 1.5 mm.

Figure 6 shows the ventral view of the pupa at the left and the ventral view in outline at the right.

THE COCOON.

The larva spins rather copiously and when fully mature it makes a cocoon of silk, coated somewhat irregularly on the outer surface with frass and other accumulations. A cocoon before the writer measures 7 mm. in length and 2.8 mm. in width, being subcylindrical and a little larger at the end where the head rests than at the anal end. The cocoons vary considerably in appearance, some being much flattened as shown in Plate II. The one described was deposited on a dry husk and partakes of the faded gray color of the latter.

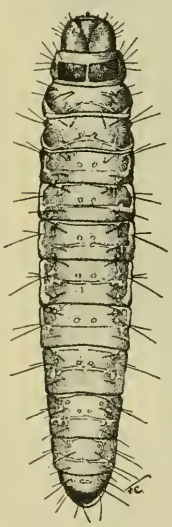


FIG. 5.—The pink cornworm: Full-grown larva, dorsal view. Enlarged. (Original.)

DISTRIBUTION.

As has already been stated, this species has thus far been found most abundantly in Mississippi but it inhabits all of the States bordering on the Gulf, as also Arkansas, Tennessee, South Carolina, and Georgia. (Fig. 7.) The southernmost point from which it has been reported is Brownsville, Tex., and it is without doubt present in Mexico. The most northern point is in Tennessee. The species is also found in Hawaii and may be native to the Orient, although we have no record of this. The probabilities are that it is not indigenous to Hawaii but may be to Mexico and our Gulf States.

RECORDS OF INJURY.

The reports which follow are not verbatim but they give a very good idea of the nature of injury in different localities and the opinions of practical growers in regard to losses and danger of future injuries.

INJURY DURING 1914.

November 9, 1914, Mr. W. B. Thomasson, jr., Murfreesboro, Ark., sent many ears of old, musty corn, badly injured by the pink corn-

worm as evidenced by abundant webbed-up excrement. He stated that this species, together with the rice weevil, whose presence was shown by characteristic holes in the corn, was at that time destroying all corn in the crib throughout the country, and that if not prevented from so doing the "worms" would destroy all the corn there.

November 28, Mr. R. W. Harned, entomologist, Mississippi Agricultural and Mechanical College, Agricultural College, Miss., sent specimens of corn which were badly infested with this small pink larva. He wrote:

During the past few weeks we have received dozens of complaints from correspondents in regard to the damage caused by these insects. Some claim that practically all of their corn has been consumed by these small "pink worms." Many who claim to have raised corn for years state that they have never before seen anything of this kind. Although I have received dozens of samples of these insects I have so far been able to rear only one adult or moth, and I have noticed only one kind of larva. They are these little pink larvæ that make webs wherever they go. In some cases they eat the entire grains.

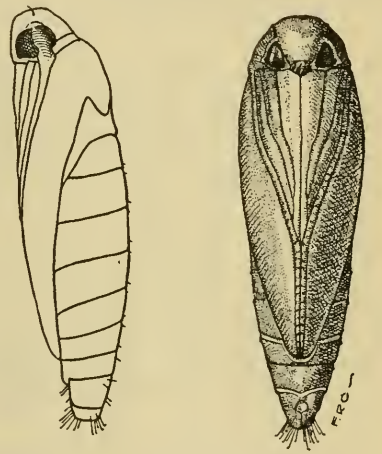


FIG. 6.—The pink corn-worm: Pupa, ventral view at right, lateral view at left. Enlarged. (Original.)

In order to furnish you with an idea as to what farmers in Mississippi think about the pink corn-worm I quote from a few letters on file as they come to me:

Mr. W. M. Taylor, Kilmichael, Miss., wrote, "I am sending specimens of small pink worms which are doing considerable damage in this section to stored corn."

George M. Bates, Union, Miss., wrote, "There is a small worm of a reddish color eating up the corn in the bins. I want to know the origin of this worm and what remedy to use to stop its work."

J. H. Rice, Sardis, Miss., wrote, "I have inspected and find a small red worm in every ear of corn. * * * It seems to be eating the corn severely. I have looked at several other places around Sardis and find them in every place."

C. S. Tindall, Winona, Miss., wrote, "I am sending some pink worms found in my corn. Every ear has from 1 to 50 worms and the corn that has *been in the barn longest seems worst infested.* The recent cold weather did not kill them on the corn in the fields."

Jason N. McColl, McColl, Miss., wrote, "Am inclosing small box of worms which are very numerous in everyone's corn in this section."

L. P. Bell, West, Miss., wrote, "We find a small pink-colored worm in our corn. *They enter the grain at the little end next to the cob and eat up the grains.* Some farmers report that cribs of corn have been destroyed in places. Investigation shows that they are in all cribs of corn in more or less quantities and the farmers are becoming very uneasy for fear the entire corn crop will be devoured. They appear to be worse in damaged corn but are found in sound ears too."

G. C. Tucker, Tyro, Miss., wrote * * * "I am sending an ear of corn. You will see how it is damaged. My entire crop is infested with this insect; in fact, it is almost half ruined. I want to crib my corn at once but an afraid to do so in the condition it is in."

M. D. Doss, Dossville, Miss., wrote, "I am sending an ear of corn which has some kind of a worm in it that is eating it up. It is a very small pink-looking worm. I have heard a great many people in this community talking about this worm in their corn. Please tell me what it is and how to get rid of the same."

W. H. Ellard, Kosciusko, Miss., wrote, "Would like to know what to do for my corn. I find a small pink worm about the size of a large needle. They seem to work from top to butt. Would like to know what to do to destroy them at once. I have 600 bushels infested this way."

W. L. Synnott, Embry, Miss., wrote, "The corn in this section is infested with a small pink worm which seems to be doing considerable damage."

J. B. Harris, Stewart, Miss., wrote * * * "I am sending you an ear of corn infested with a worm that I am informed is destroying entire cribs of corn in some sections. Practically all of the corn in this section is more or less infested."

FIG. 7.—Map showing distribution of the pink corn-worm in the United States. (Original.)

L. L. Wilson, Ethel, Miss., wrote, "There is a little red worm eating my corn—doing a lot of damage."

J. W. Johnson, Rio, Miss., wrote, "I am sending you specimens of worms that are eating up everybody's corn in this country."

On December 8, Mr. Harned again wrote in regard to this species, furnishing the following notes concerning correspondence during November:

* * * "From the large number of letters that I have received this pest is undoubtedly most serious in Attala County and the counties immediately joining it. There can be no doubt that this insect is causing an immense amount of damage in this State at the present time. The farmers have become excited about it and many have called me over the long-distance telephone and every mail brings in letters in

regard to it. We find the ears infested in the fields as well as in the cribs. I am sure that they work on sound cobs.

Mr. L. P. Bell, West, Miss., whose letter has just been quoted in brief, wrote:

> Investigation shows that they are in all cribs of corn * * * the farmers are becoming uneasy about the crop. They appear to be worst in damaged corn but are found in sound ears too.

Mr. Thos. H. Jones, who has been working under the writer's direction, makes practically the same statement, and Mr. J. B. Garrett, Assistant Director of the North Louisiana Experiment Station, Calhoun, La., under date of November 24, 1915, wrote as follows:

> It would appear from my observation, which of course is rather limited, that the "pink corn-worm" is found in ears of corn most frequently where they have been previously injured by bollworms, birds, etc., *but I have seen them in ears which were perfectly sound and showed no signs of other injury.*

We must accept this as the truth in spite of the fact that the writer and several others have never seen any infested ear of corn which was not first attacked, if ever so lightly, at the tip of the husk by the bollworm or some other insect, giving ample opportunity for the moth of this species to deposit her eggs.

On December 2 Mr. W. H. Horne wrote from Laurel, Miss., that his community was thrown into considerable confusion by the discovery of a little pink corn-worm which was doing damage to many cribs of corn. As the pest seemed to be comparatively new he was desirous of any information that would enable the growers to stem its ravages. He desired also a personal visit from an agent of the department.

The Bureau of Entomology received later, through Hon. T. U. Sisson, a communication from Mr. W. B. Rainey, Hesterville, Miss., stating that there was a little worm known as the "pink worm" in that country eating the corn after it was cribbed. Information in regard to some remedy was urgently requested. The statement that the insect formed a web at the little end of the ear, and from there proceeded downward eating and webbing, left no doubt that this was the species in question.

On December 5 Mr. R. P. Wright, wrote from Carthage, Miss., amply describing this insect, saying that it threatened to destroy the corn in that vicinity, and that numbers were imbedded in almost every ear of corn, which they ate most voraciously.

INJURY DURING 1915.

During January, 1915, ears of corn showing average infestation of the pink corn-worm were received from Mr. K. H. Diggs, Lexington, Miss.; there were three varieties of corn taken from five different cribs. The corn was planted between April 5 and May 10, and har-

vested in October and November. Mr. Diggs reported that he found the worst damage in immature or imperfect ears where the bollworm or birds had attacked the ear.

During the last days of December, and on January 1, this species was reared from different lots of corn received from Mississippi. One of these localities is Sardis; another is Batesville. The material was received about November 19.

Twenty ears of corn were received on January 7 from Mr. Thos. H. Jones, of the Bureau of Entomology, Baton Rouge, La.; all were imperfect, every ear having been injured and much stunted by the corn-ear worm (*Heliothis obsoleta*). The larval forms of *Batrachedra rileyi* were crawling over the husks of the corn in great numbers, as also on the inside of the bags, seeking a suitable spot for pupation. There were approximately 400 larvæ of various sizes. The larvæ worked on the underside of the grain, especially in the decaying grains or parts of the ears, but the actual damage resulting in this instance was not great. Pupæ were also found in various places—in the husks, beneath the hollow grain, in the cob, and among the castings on the ear. Mr. Jones wrote as follows:

> Larvæ were common in undeveloped and poorly formed ears of yellow flint corn in a field at Baton Rouge, on January 2. The valuable ears had been pulled from the stalks in the fall, the stalks at present being dead and brown and, for the most part, still standing. The larvæ were found beneath the husk, working on the surface of the cob among the remains of the kernels, many of which have never matured.

January 29, Mr. J. J. W. Smith, Waterford, Marshall County, Miss., sent three ears of corn badly infested with the little worms. They were described as doing much damage to the corn.

> They go from one end to the other in the heart of the corn. Shucking the corn out is the best and safest way to save the corn. Cold weather does not seem to have any effect on them while the shuck is on the corn. But when the corn is shucked and knocked about it helps the corn and does not give the worms such a good chance.

February 1, Mr. W. T. McDonald, Bailey, Miss., sent specimens working in corn ears injured by the corn-ear worm, with the statement—

> we attribute the heavy infestation of the worms this season to the extreme dry weather while the corn was making. I find on my place that the corn worst hurt by the drought is worst infested by the "worms." * * * I have never had any experience with the pest prior to the present season, and I may be in error.

Similar complaints were also received of injury to corn from various other localities, as follows: Brownsville, Tex., reported by M. M. High; Lawrence, Union, Saltillo, Harris, Louin, Battlefield, Chunky, Coila, Beach, and Thyatira, Miss.; Fayette, Ala., and Scott, Ark. The insect has been reported by Prof. J. M. Beal, Agricultural College, Miss., to have attacked Kafir corn. During November of 1915 complaint of injury by this species was made at Quitman, Miss.

January 16, 1915, Mr. C. E. Smith collected in the field at Baton Rouge, La., and sent to the writer several cobs of corn in the husk. The cobs were poorly formed, most of them having few developed grains, and they showed old work of the corn stalk-borer (*Diatraea saccharalis* Fab.) and of the corn-ear worm. A number of adults of the rice weevil (*Calandra oryza* L.) were present in the husks, and adults of *Cathartus gemellatus* Duv. were abundant in the same situation.

The pink corn-worm was found among the leaves of the husk, in the kernels, and in the cob itself. Larvæ of various sizes were present, but were mostly nearly full-grown, judging from some that were observed in silken cocoons in all locations where larvæ were observed.

It was difficult in this case to estimate how much feeding had been done on the husks, kernels, and cobs by the Batrachedra larvæ because of the injury by, and the presence of, other insects. Larvæ of *Cathartus gemellatus* and of *Sitotroga cerealella* were also present and may have caused some injury. It seems, however, that a part of the silk and most of the small pellets are due to the work of the Batrachedra larvæ and that some of the cavities in the kernels were due to them.

Messrs. Thos. H. Jones and C. E. Smith found the pink corn-worm in various sizes, some apparently full-grown, working on ears of sweet corn, in company with several other species. In some ears they were working where the husk was still green and in some cases where the husk had begun to dry. The larvæ followed attack by other insects, or where from some other cause a portion of the ear had become exposed as from injury by birds, and "nipping off" of the tips by a horse, etc. In many cases the ears in which they were working were in bad condition, being so injured as to be of little value.

At Baton Rouge, La., on July 24, 1915, moths were placed in a jar containing yellow cornmeal with a piece of sponge moistened in sweetened water, the jar being placed in the insectary. The first moth, coming from eggs laid by moths placed in the jar at this date, was noted on September 30. The time taken for the development would indicate, when compared with the rate of growth on other substances, that cornmeal is not a particularly good food for the larvæ. It will be noted here that it was possible to rear this insect in cornmeal in experiments conducted at Washington. Another point should be made, namely, that infestation in Louisiana has not been anywhere near as severe as in Mississippi, and that most of the corn ears received from the latter State were in exceedingly bad condition.

EARLIER RECORDS.

From correspondents of the Bureau of Entomology we have had this species from Colquitt, Perry, and Atlanta, Ga., and New Orleans, La., in cotton bolls.

In September of 1894 and again in November, 1895, specimens in the several stages, together with ears of corn in which the insect was living, were kindly sent the writer by Mr. E. A. Schwarz, who gathered them in the field at Baton Rouge, La., and Beeville, Tex., respectively.

June 6, 1909, Mr. D. K. McMillan sent some of this species feeding in the seed-heads of sorghum from Kingsville, Tex. About the same time he sent specimens of what he described as "pink larvæ," common under the shuck on corn ears, from Santa Maria, Tex. Later he sent more material from Kingsville, Tex., from which six adults were found on June 25, three on July 10, one on July 12, and more on July 13, 16, and 26. On June 20 he found this species working in corn in the husk at Beeville, Tex. November 9 of the same year the larva was again found in the heads of sorghum.

During 1912 specimens were received from Mr. M. M. High, Bureau of Entomology. On February 16 they were found working on corn. Seven living larvæ were placed in cornmeal and all died in two days.

During 1913 this species was received in dasheens (*Colocasia* sp.) from Mr. R. A. Young, Brooksville, Fla. The adults issued December 3 and continued to issue from the dry corms.

HISTORY AND LITERATURE.

Our early literature bearing on the biology of this moth, if we except line notices and brief mention,[1] is contained in the accounts of Townend Glover. In his first two entomological reports (Glover, 1855, 1856) its habits are described and the insect in its several stages figured. In the first article the species is treated under the name of "grain moth (*Tinea?*)"; in the second as the "corn worm (*Heliothes?*)." Afterwards in his Manuscript Notes from My Journal, or Entomological Index (Glover, 1877) the same writer refers to this species as *Tinea granella*, throwing the responsibility of its previous determination as "*Heliothes?*" upon D. J. B[rowne]. He found it in the cornfields of South Carolina and Georgia in September and says: "It infests the cornfields, where it is sheltered by the husks, and burrows between the grains, upon which it feeds, somewhat in the manner of the Angoumois moth, except that the kernels are more irregularly eaten," and that "these worms also appear to attack corn out of the field as well as in." Beyond this statement the writer is not aware that the insect has ever been mentioned as occurring in the granary, but from personal experience several years ago it was learned that it feeds upon the ripened corn and is perfectly capable of living indoors and that it unquestionably does so. Whether it is possible for the species to breed *ab ovo* in stored, i. e.,

[1] In the American Entomologist for May, 1880 (v. 3, p. 129), and again on page 121 of the appendix of the Fourth Report of the United States Entomological Commission, incidental mention is made of this species with the comment that, according to Chambers, it is a new species of Laverna.

dry, grain, it was at that time impossible to say. Glover also mentioned the occurrence of the insect in cotton bolls that had previously been pierced by the bollworm or split open by the rot.

In an article on the cowpea-pod weevil (*Chalcodermus aeneus* Boh.) the writer (Chittenden, 1904) mentioned the fact that the holes left in the pods affected by this weevil, which were formed by cracking or otherwise, led to secondary infestation by other insects. Among those reared during that year from cowpea was the species under consideration.

In a paper by Mr. E. S. Tucker published in 1911 (Tucker, 1911) mention of this species is made as follows: "Larvæ of this moth were frequently found in fallen bolls associated with and without *Araecerus fasciculatus* or its work. The larva is supposed to feed on insect remains." Again in the same article Mr. Tucker notes the finding of the same species at Alexandria, La., September 18, 1908, "in cornstalks infested by *Araecerus fasciculatus*, or where the latter had worked and left, and decay had begun," * * * "particularly in rotting, rain-soaked stalks"; the adults maturing in the breeding cage October 22–29. Mr. Tucker also reports that he found it "in green cornstalks, and sometimes in ear tips injured by the corn worm, *Heliothis obsoleta* Fab., at same place, August 2, 1909," and that "Mr. J. D. Mitchell submitted pupal cases taken from Araecerus cavities, in cornstalks at Victoria, Tex., March 7, 1909."

In his article on insects which affect the cotton plant, Dr. L. O. Howard (Howard, 1896) mentions this species in connection with its occurrence in young cotton bolls, and states that there was a general belief among planters that the species acts independently of cotton-worm damage. He added:

> This statement, however, has not yet been satisfactorily substantiated so far as it refers to the bolls. In the young squares, however, the active little reddish larva of this Batrachedra is very often found as unquestionably an original inhabitant, and it undoubtedly frequently causes quite an extensive shedding of the squares. This, however, occurs only in the spring, at a time when there is a surplus of bloom and when many squares can be spared without great reduction of the crop. Later in the season the Batrachedra larva is found boring in the unopened flower heads of various weeds.

The following year the writer (Chittenden, 1897) published some notes on this species, identifying Glover's corn-feeding tineid as *Batrachedra rileyi*.

In 1909 Mr. Otto H. Swezey (1909) repeats Walsingham's description and states that the larva was found in Hawaii feeding in various situations, most frequently on dead vegetable matter or refuse substances, and that therefore it was not particularly injurious. The larva was observed feeding beneath leaf-sheaths of dead cane; also in "borered" cane stalks in places where the leaves were dirty and sticky from the attack of aphides or leafhoppers. It was also found working in the tassels and very numerous in sweet-corn ears, feeding

on the "silks," inner husks, pith, and other parts of the cob; also in ears of field corn, eating into the kernels and cobs. At another time he observed it on a large woody twining bean vine, feeding on dying leaves and ripening pods, especially where there was an accumulation of webs and frass, or where other insects had been at work. Among other food plants he mentioned lantana, palm leaves, and the dead leaves of Pandanus, banana, and "various other plants." On banana the larvæ fed in the bunch on the dead or injured fruit and on the skin of the ripened fruit which they sometimes punctured, even eating into the fruit within.

ASSOCIATED INSECTS.

It has already been reported that this species usually follows the attack of the corn-ear worm (*Heliothis obsoleta* Fab. [Pl. I]), which is true of most other forms of stored-grain insects in the South. At about the same time the rice weevil (*Calandra oryza* L.) enters the corn but does not seem to work with the same rapidity as does the species in question. Later, in all probability, another species which is quite common, the square-necked grain beetle (*Cathartus gemellatus* Duv.) enters the ears and causes considerable damage both in the field and in store. This same insect is often found associated with the pink corn-worm in cotton bolls, and breeds in the same. The rice weevil occasionally enters cotton bolls, especially when they are on the ground, but does not breed in them, merely entering them for shelter or for hibernation. The Angoumois grain moth (*Sitotroga cerealella* Zell.) also breeds in corn with the species under consideration but thus far has not been found in many instances. It was observed at Agricultural College, Miss., in a sending dated November 28. The sorghum midge (*Contarinia sorghicola* Coq.) was also found associated with the pink corn-worm in sorghum seed from Brownsville, Tex., collected by A. K. McMillan, Nov. 9, 1909. A common moth ([*Nola*] *Nigetia sorghiella* Riley) was found in the same lot with the sorghum midge and it is probable that in this case the pink corn-worm followed attack of the Nigetia moth.

Among other associated insects are the foreign grain beetle (*Cathartus advena* Walt.) and the coffee-bean weevil (*Araecerus fasciculatus* De G.). The former is of comparatively little economic importance, feeding for the most part on stale grain, fruits, and other stored material, being naturally of a scavenging nature. Nevertheless, it has been quite troublesome during the past two years. The latter attacks coffee beans, mace, dried figs, and various other dried articles of commerce, and is also found somewhat commonly in diseased cotton bolls. A small ortalid fly (*Euxesta anonae* Fab.) was reared January 29, 1914, from dasheen (*Colocasia* sp.) affected with the pink corn-worm. This last species is without doubt a natural feeder on dasheen, but no record of its habits is available.

To show how severe is the injury wrought by the pink corn-worm, an ear of corn which has been infested only about 10 months is shown in Plate III. The larvæ were swarming under the husk, which has been removed to show the extensive webbing and injury to the kernels. For comparison with this is shown another ear of corn (Pl. IV) which was infested originally by the Angoumois grain moth and afterwards by the Indian-meal moth and rice weevil. At the time the photograph was made the Indian-meal moth had escaped, leaving its webbing. The latter ear weighs about twice as much as the former. The ear in Plate III was the best that could be found out of eight infested by the pink corn-worm, while that in Plate IV was picked at random to show the holes made by the Angoumois grain moth in escaping from the kernels and the extensive and peculiar webbing of the Indian-meal moth. In Plate III the pink corn-worm was still working in numbers, but in Plate IV neither of the moths mentioned could be found in any stage. While the ear in Plate IV had been held in store for two years, that in Plate III had been stored only 10 months.

NATURAL ENEMIES.

For some unexplained reason this insect appears to have few natural enemies, only one parasite having been reared. It is more than probable, however, that some predaceous insects, as well as bats and nocturnal birds, attack the moth when in flight in the fields and about the infested cribs. From larvæ received from Mr. E. A. Schwarz in cotton bolls gathered at Virginia Point, Tex., December, 1878, an ichneumon parasite issued March 3, 1879, and was identified as *Pimpla* sp. (U. S. D. A. No. 1041 P.°).

METHODS OF CONTROL.

Assuming that the damage in Mississippi and other States in the South is due largely to increased production of cotton and to the fact that it follows attack by the bollworm, it is suggested that if we could successfully combat the bollworm or corn-ear worm it should have a decided effect in lessening the numbers of pink corn-worm.

The corn should be gathered and husked as soon as possible, and the ears showing infestation by the pink worm should be fumigated immediately or fed to swine or poultry. This would prevent the infestation of other corn in store. Particular attention is called to this method of treatment since in some parts of the South it is customary to gather corn by "snapping" the ears, these afterwards being stored with the husks intact. This practice especially favors the development of certain grain-feeding pests, including the pink corn-worm. Moreover, the closeness of the husks renders successful fumigation by means of carbon bisulphid nearly impossible.

The additional handling incident to the husking process is also of benefit, as many of the larvæ are dislodged thereby, and the husked ears afford little concealment for pupation and for the feeding of the larvæ.

The best ears when dry could be saved to a considerable extent by placing them in an isolated weevil-and-mouse-proof fumigator such as a metal crib, to be made as nearly air-tight as possible.

CARBON BISULPHID.

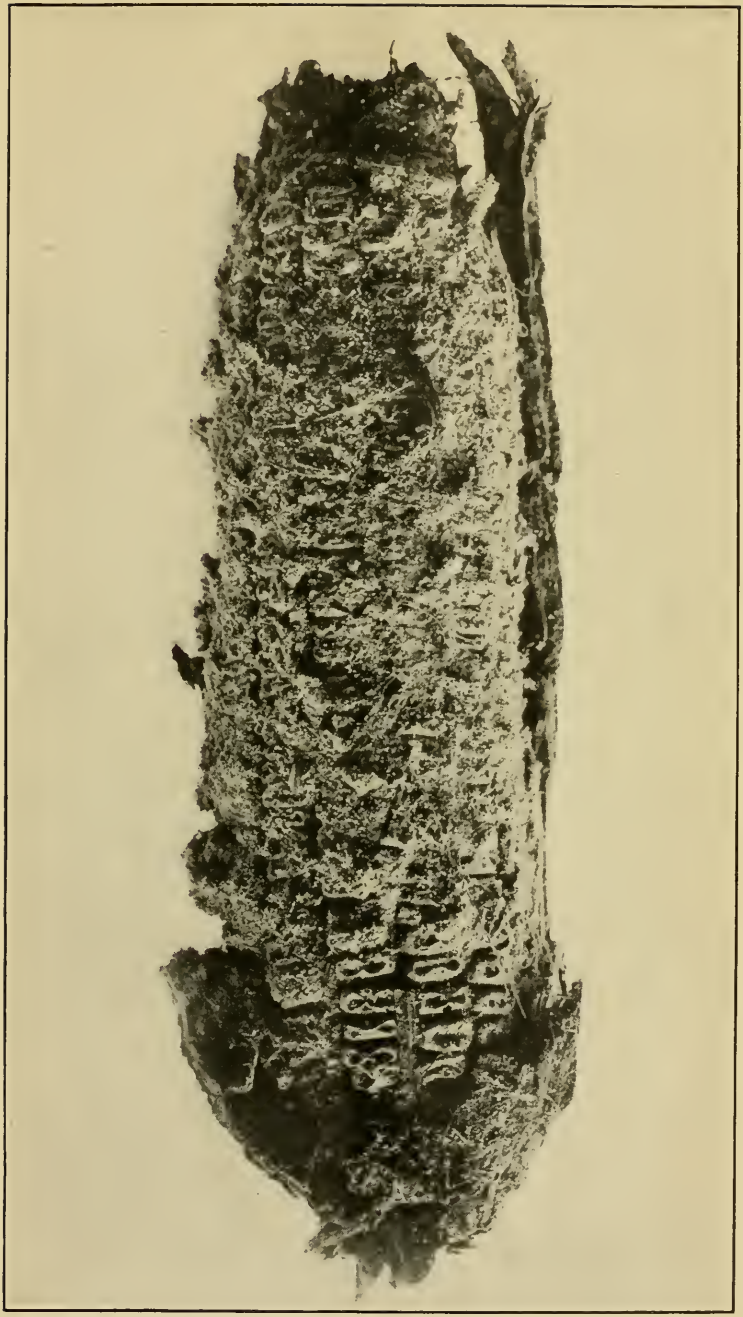
In the South, where the pink corn-worm is so injurious, bisulphid of carbon is the best remedy and has already been used for its control. Carbon bisulphid, or bisulphid of carbon (CS_2), is a heavy liquid, colorless when pure, and is one of the standard chemicals for the control of insects injurious to stored products. Its value lies in the fact that it is extremely volatile, passing into the open air as a heavy gas which settles to the bottom of receptacles in which the liquid is exposed and, by replacing the air, causes suffocation. It is much used against the Angoumois grain moth and various other insects injurious to corn and other cereals. It is less poisonous to human beings than hydrocyanic-acid gas and, while there is danger from fire owing to its inflammability, with a reasonable amount of care this chemical may be cheaply and effectively applied to almost any stored product infested by insects.

It is more effective at a high temperature, 76° to 90° F. proving the best for its use. It is less effective under 70°, and not efficient as low as 50° F.

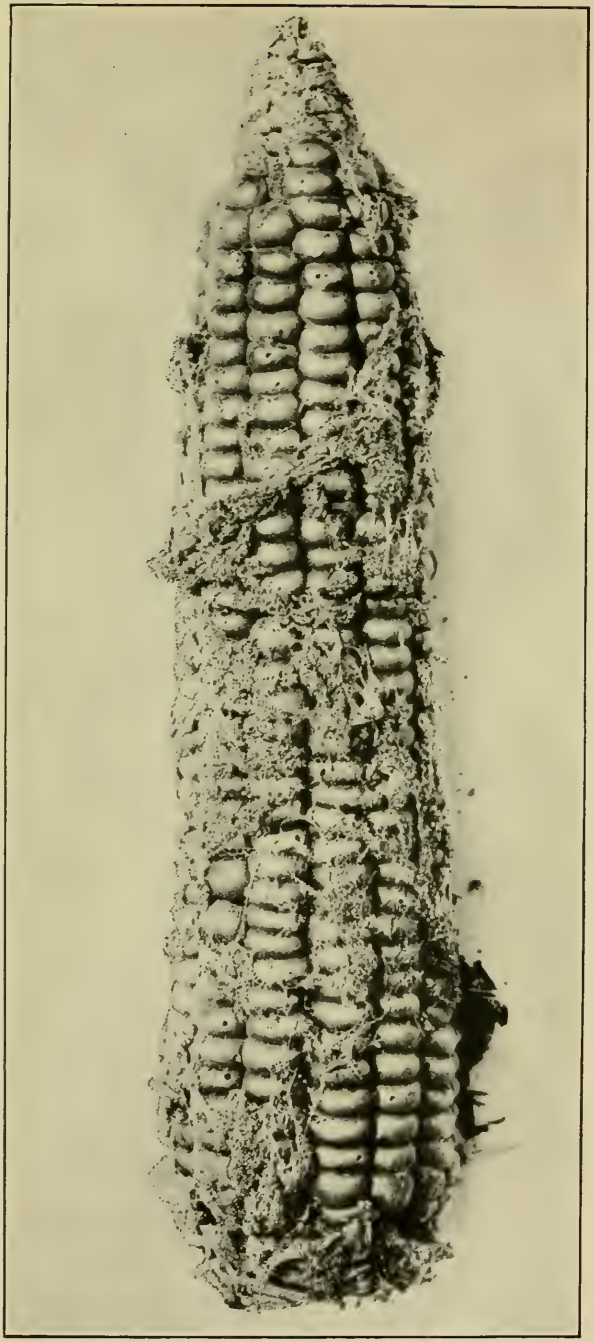
DIRECTIONS FOR USE.

Since carbon bisulphid is extremely volatile, it is best evaporated in flat vessels—milk pans, pie tins, and cheap plates serving this purpose admirably. An average application is 2 or 3 pounds to 1,000 cubic feet of air space, or 1 pound to 100 bushels. Less may be used, but it has been found that in a structure which can not be made positively air-tight it is necessary to use this amount to insure success. The liquid is poured into the evaporators, a half pint or more in each, and, as the gas is heavier than air, the evaporators are then placed in the higher parts of the bin or fumigator. Evaporating pans are frequently set on the top of the grain, allowing the gas to penetrate to the bottom, or, in the case of shelled corn, a perforated tube, such as a drive-well point, may be thrust into the grain and the requisite amount of the liquid poured therein.

When the gas is used in open bins or other receptacles the surface of the grain should be covered with heavy tarpaulin or canvas. The bin should be kept closed as tightly as possible for about 36 hours; this will not destroy the germinating power of the seed. With grains not desired for planting the bins may be allowed to remain closed as long as the gas evaporates.



EAR OF CORN FROM WHICH THE HUSK HAS BEEN REMOVED TO SHOW SEVERE INJURY BY THE PINK CORN-WORM. (ORIGINAL.)



CORN EAR SHOWING INFESTATION BY THE ANGOUMOIS GRAIN MOTH (SITOTROGA CEREALELLA) AND AFTERWARDS BY THE INDIAN-MEAL MOTH (PLODIA INTERPUNCTELLA). (ORIGINAL.)

The pink corn-worm and associated insect pests which have been mentioned enter the seed of grain in the field, so that treatment is most effective if made as soon as possible after harvest.

In the case of small quantities of seed a tight barrel may be used as a receptacle. One or two ounces of carbon bisulphid may be placed in a small saucer or pie tin upon the top of the grain and the top of the barrel covered with heavy cloths or oilcloth.

In the fumigation of a large building at least two, and preferably three, men should assist in the operation. The building should be tightly closed and the pans or containers for the liquid distributed about the building. Then, as far as possible, the work should be begun in the lower parts of the building, working toward the top. After the cubic capacity of the building and of the separate rooms has been computed, the requisite quantity should be divided among the pans in each room, about one pan to each 100 square feet of floor space being used. After the liquid has been poured into the pan the room should be left at once and the other parts of the building treated in the same manner. While the gas is not immediately fatal, it is well not to inhale too much of it, since nausea and severe headache are likely to result. After the building has been treated in the manner mentioned, exit should be made promptly and the doors tightly closed.

At the end of the period of exposure doors and windows should be opened wide so that the gas may escape. One or two hours should then elapse before work is resumed in the building. A slight odor may still linger in the poorly ventilated corners of rooms but there will be no danger to occupants from the gas, and the odor will gradually disappear with ventilation.

PRECAUTIONS.

Particular attention must be called to the danger from fire due to the presence of carbon bisulphid in the air, and special reference should be made to it in connection with the treatment of buildings.

The danger of bringing a lighted cigar or other lights, such as a lantern, into the presence of the gas must always be borne in mind, since in at least one case an explosion of considerable violence was caused by such carelessness.

The application should always be made in daylight, as no artificial light of any kind is allowable. Even electric lights may not be used, since there is always danger from the sparks caused by turning them on and off. Electric and other motors and steam pipes should be turned off, that no danger may result from the sparks or heat.

Owners of adjoining premises should be warned as to the character of the work that is being done and the need for care if vapor should penetrate their rooms to any extent.

It would be an added measure of safety if a watchman were kept on guard on the premises from the time the application is made until ventilation is complete. It would also be well to place large "DANGER" signs on the doors.

OTHER REMEDIES.

Among other remedial measures storage of corn in large bulk is recommended, since the surface layers of shelled corn or other grain are most exposed to infestation while the lower portions are not so apt to be injured, if at all. The larvæ could penetrate corn in the ear to a considerable depth, but, as their life is short, this is probably seldom done. The moths are unable to do so. Agitation applied to a mass of grain is also destructive to the moths, since they are unable to extricate themselves and perish in the attempt. Cold storage may be employed for valuable seed corn, and naphthalene balls may be used for the same purpose. The most scrupulous cleanliness should always be observed, much injury due to stored grain insects being directly traceable to disregard of this. Old grain and refuse material containing sweepings of grain, dust, dirt, and rubbish in general should not be allowed to accumulate and serve as breeding places for injurious insects.

In conclusion, it should be stated that promptness is absolutely necessary for the control of the pink corn-worm and that bisulphid of carbon can not be profitably used in open cribs, so that if this insect continues its ravages it may be necessary to construct special fumigating buildings and to store the corn in tighter receptacles than the cribs and bins now used.

SUMMARY.

1. The so-called pink corn-worm is not a true worm, but the caterpillar or larva of a minute moth known as *Batrachedra rileyi*.

2. Attack on corn begins in the field and continues after the corn has been stored. When the stored product is husked, the infested ears show injury by accumulations of webbing and frass or excrementitious matter. A careful inspection discloses the "pink worm."

3. The eggs are deposited in the field where the tips of the corn ears are more or less open, due to the attack of the corn-ear worm. After the latter has departed the pink corn-worm continues the injury and by its work makes it easy for other insects and water to enter the ears, which eventually are ruined.

4. From the cob or between the rows of grains the worm penetrates the kernels at the tip or point of attachment, works into the embryo or "germ," which it destroys, then outward to the crown.

5. Unlike the Angoumois grain moth and the rice weevil, which are usually to be found working in the same fields and frequently in

the same ears, this "worm" does not confine itself to the kernel, but attacks kernel, husk, and cob alike.

6. Also, unlike most other grain pests, it appears to be confined among cereals to corn and sorghum, although it attacks, but does not seriously injure, cotton bolls which are more or less open, and some other plants.

7. While thus far it has proved most injurious in Mississippi, it ranges from South Carolina westward to central Texas, southward to tropical Texas, and northward to Arkansas and Tennessee.

8. During the years 1914–15 the pink corn-worm was reported to have occasioned very considerable injury, and much alarm was felt because of its abundance in the regions mentioned. Previously, although known to attack corn, it has never been considered a serious enemy of grain.

9. Naturally it can not be foretold when, if ever, such an outbreak will recur.

10. As a preventive of injury, corn should be left in the field no longer than is absolutely necessary for drying it; the husks should then be removed as soon as possible, the poorest of the infested ears destroyed promptly or fed to swine or poultry, and the best ears fumigated with carbon bisulphid according to the directions given on previous pages.

11. The bins or cribs should be kept scrupulously clean, and should be fumigated before new material is stored in them.

12. Cooperation among corn growers of as large a territory as possible where the species occurs should be secured, that future losses may be prevented.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 377

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER August 18, 1916

THE ARGENTINE ANT:[1] DISTRIBUTION AND CONTROL IN THE UNITED STATES.

By Ernest R. Barber, *Scientific Assistant, Southern Field Crop Insect Investigations.*

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INTRODUCTION.

The Argentine ant[2] is one of the most serious of household pests. Any exposed food or food refuse in the infested sections attracts the workers of this species in abundance, and residents and keepers of grocery stores, meat markets, confectioneries, etc., must either suffer considerably or almost constantly use poison or barriers of various kinds. If its activities were confined to the household only, the problem of controlling the Argentine ant would be sufficiently difficult, but in common with some other ants it has the habit of protecting mealybugs and aphids and thus indirectly becomes a pest of crops.

The problem is more serious from the fact that the species is steadily spreading in all directions throughout the Southern States. It is practically certain that it was introduced into this country at New Orleans, in ships which brought coffee from ports in Brazil, although the exact date of this introduction will always remain in doubt.

The Argentine ant was first observed in New Orleans in 1891 by Mr. Edward Foster.[3] At that time he records it in small numbers

[1] The work of the Bureau of Entomology on the Argentine ant is divided into two parts. One part deals with the ant as a general pest, its distribution, and relation to the cultivation of sugar cane. The other part relates to the special problem of control in citrus groves. This phase will be treated in another publication. The work reported in this paper does not include reference to conditions in California, parts of which State are also infested by the Argentine ant.

[2] *Iridomyrmex humilis* Mayr.

[3] Foster, E. The introduction of *Iridomyrmex humilis* (Mayr) into New Orleans. Jour. Econ. Ent., v. 1, no. 5, p. 289–293. 1908.

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nine blocks east of the wharves at which the coffee ships usually discharged their cargoes. It may be surmised, from the knowledge we have since gained from studying the natural dispersion of this insect, that it has been in the country for about 45 years. During that period it has expanded from the original colony to myriads of colonies, extending its area of distribution into nine Southern States, the many infestations covering a total area of considerably more than a thousand square miles.

PRESENT KNOWN DISTRIBUTION IN THE SOUTHERN STATES.

Newell and Barber,[1] writing in 1913, recorded the known distribution in the Southern States as confined to Louisiana, Mississippi,

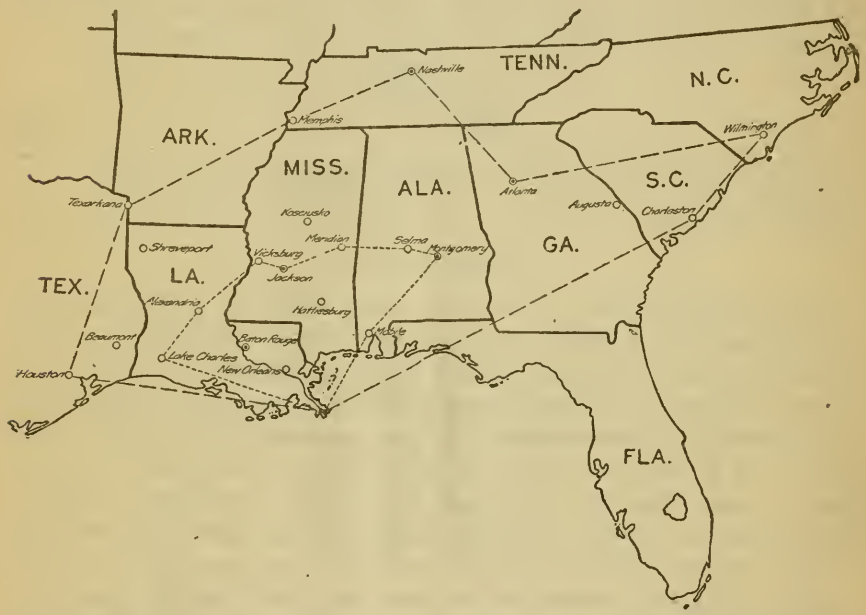

FIG. 1.—Map showing the distribution of the Argentine ant in 1913 (inner line of small dashes) and at the end of 1915 (outer line of longer dashes). (Original.) The outer line has been drawn merely to connect the outlying points. It incloses some territory in which the ant is not known to occur, as, for instance, western Florida.

and Alabama, and established the limits of this dispersion from Montgomery, Ala., on the east, to Lake Charles, La., on the west, a distance of 380 miles, and from Delta, La., on the north, to the mouth of the Mississippi River, a distance of 250 miles. At the present time the limits of the distribution are from Houston, Tex., on the west, to Wilmington, N. C., on the east, and from Nashville, Tenn., to the mouth of the Mississippi River, a distance of 1,100 miles east and west and 500 miles north and south (map, fig. 1). Among the cities known to be infested are Houston, Tex., Shreveport, La.,

[1] Newell, Wilmon, and Barber, T. C. The Argentine Ant. U. S. Dept. Agr. Bur. Ent. Bul. 122, p. 14. 1913.

Texarkana, Ark., Nashville, Tenn., Memphis, Tenn., Augusta, Ga., Atlanta, Ga., Charleston, S. C., and Wilmington, N. C.

DISPERSION.

Under natural conditions the Argentine ant spreads very slowly, and this spread is controlled to a large degree by the available food supply. Like most other species of ants, the Argentine ant is a very industrious forager, and a shortage of food tends to hasten its dispersion. In October, 1914, a small infestation covering the most of two city blocks was found in Memphis, Tenn. The ant numbers could not have increased to any appreciable extent during the rather long and cold winter of 1914–15, and yet in the early part of the following June the infestation was found to involve nearly the whole of five blocks. In October, 1915, it developed that the boundaries had not been extended, though the ant numbers had greatly increased. The food supply must have increased as fast as did the numbers of ants.

In several instances frequent observations made at points on the frontier of the infestation developed the fact that the normal advance will average from 300 to 400 feet a year. The abundance of native ants has some influence on this advance, since the Argentine ant will not tolerate any of the native species, and in consequence a continuous fight is waged all along the frontier.

Heavy, flooding rains are undoubtedly a factor in the natural distribution of this ant, and in the vast region drained by the Mississippi River and its tributaries it will be remembered that there are at least two dangerous flood seasons and sometimes more, which contribute to and accelerate the distribution of this species. Lumber, rotting trees, uprooted shrubs, cane growth, fruit, vegetables, and all manner of refuse contribute to the mass of matter borne on the crest of flood water, and in this the ants seek refuge and are involuntarily transported. Nature has endowed this species with a remarkable habit of self-preservation from drowning in times of floods, for when rising water floods their nests and no other means of escape are presented they cluster together and form a compact ball. The immature stages form the center of this ball, with the queens and workers as the outer portion. As the ball enlarges from the addition of other workers which had been struggling alone in the water it gradually revolves. It is kept revolving slowly by the outside workers continually striving to reach the top of the ball, thus permitting air to reach the interior. The writer has had only one opportunity of witnessing the formation of a ball of this kind. After a 5-inch rainfall several balls, none more than 2 inches in diameter, were observed. According to reliable authorities, such balls have been observed on many occasions, some of them from 6 to 8 inches in diameter. The ants in

these balls disperse when they come into contact with a secure resting place, such as a floating piece of timber or land, but they have been seen to float around for hours on still water. Mr. Smith, at Daisy, La., states that he destroyed a large number of these balls by pouring some coal oil on the water. The balls quickly broke up when in contact with the oil and the ants died in a very short time.

Driftwood is another important carrier of this pest. A fallen decayed log is an ideal nesting place. Such a log will usually decay from the underside upward, the upperside or top making a roof for the nest, with the rotted wood below drawing and retaining ample moisture, thus affording excellent material in which to make galleries. Logs of this kind are light and easily floated and are important factors in spreading infestations. Especially is this the case in those parts of the country where heavy, flooding rains occur. In this manner practically all the land along the Mississippi River below New Orleans has been infested.

However, it is to the vehicles of man that the greatest distribution must be credited. The most important are steamboats and railroads. Commodities are carried from infested territory to uninfested places and ant colonies are often to be found in shipping boxes, feeding on sugar and other grocery supplies. Practically every one of nearly a hundred steamboats landing between New Orleans and Baton Rouge is infested with the Argentine ant. Further, it seems likely that this ant was carried by boat from Charleston, S. C., to Wilmington, N. C., as the ant is to be found around the wharves and shipping in both places. So gross is the infestation in both these cities that it is possible that the species may have been introduced into Charleston many years ago on coffee ships, as it is supposed to have been introduced into New Orleans, the slightly colder winters holding it more in check.

When inspecting cities far removed from New Orleans it has been found that in the great majority of instances the infestations start immediately around the wholesale-grocery and commission-merchant establishments. This indicates that when carried long distances the ants are more likely to be taken through in solid carload lots of merchandise which are rushed to their destination than in smaller consignments. This is especially the case with perishable goods such as fruit and vegetables. Cars containing broken shipments are sidetracked at the first town to which goods are consigned, and the ants present are likely to leave the car at the first or second stop, which fact is verified in that nearly all the small towns for a distance of 150 miles from New Orleans are infested. A serious feature of the infestation of inland cities such as Texarkana, Memphis, Atlanta, and others, is that the ants, having become established in the wholesale district, are readily distributed to surrounding smaller towns

which are tributary to these centers. A point where such a distribution has occurred is Summerville, a little town 24 miles north of Charleston, S. C., which has become infested, presumably, from the latter place.

In a complete colony in the spring of the year three distinct forms of adults are to be found—queens, males (drones), and workers, the workers greatly outnumbering both the queens and the males. The workers, foragers of the colony, are imperfect females with no reproductive functions. The queens, which are the reproducing females, remain within the nest nearly all the time, and are fed and tended by the workers. The males have apparently but one function—that of fertilizing the queens. It will be readily understood that, as in the social economy of ant communities of other species, it is absolutely necessary that a fertilized queen be taken along with a number of workers before a new colony can be started. It is quite possible that almost every town and city in the Southern States has had a number of workers introduced at one time or another, but owing to the absence of a queen a noticeable infestation has not become established. Workers alone carried in this manner would die out. Such may be the case at Nashville, Tenn., where only a few workers have been found. Later observations will be necessary to decide this question.

ECONOMIC IMPORTANCE.

As a pest in cities the Argentine ant has no equal. Owing to its small size and unobtrusive color, it is able to invade practically every part of ordinary dwellings, stores, etc. It is almost omnivorous, eating most cooked foods and a considerable percentage of the raw foods that are to be found in the average pantry. It exhibits a marked preference for some foods, such as sugar, sirup, honey, jams, cakes, candies, pies, fruit, and meats of all kinds. The temperature of refrigerators or ice boxes seems to have no deterrent effect, and ants will readily invade them.

It is a common occurrence for Argentine ants to invade bedchambers, and while they do not possess a sting, they can cause considerable pain with their mandibles. There have been many reports of babies being attacked by them in such numbers as to cause serious results, and several of these reports have been verified. In August, 1915, the writer located such a case in Augusta, Ga. A reputable citizen of that city, residing in a heavy infestation of the Argentine ants, gave the following account of such an attack on his 4-weeks-old baby:

> We were awakened in the night by a weak cry from the baby, and when the light was turned on the baby's face was black with ants. They were in the baby's nose, ears, and mouth. We hurriedly carried the baby to the bathtub

and started to wash off the ants. It took us nearly an hour and a half to get the last ant off the baby. I feel sure that if we had not heard the cry, in a few hours the child would have perished.

With conditions made almost intolerable in badly infested places, it is not uncommon to find empty, unrentable houses. Realty values accordingly drop.

The nurseryman and truck grower are greatly molested by this pest, owing to the ant's fondness for the honeydew of aphids and scale insects. The ants take the best possible care of these honey-yielding species, and protect them from their natural enemies, frequently building mud shelters over them, and as the host plants grow, carry the young scales and aphids and place them on the young tender growth, where they may more easily sap the juices of the plants.

Newell and Barber[1] give a very graphic account of the manner in which the Argentine ant has invaded the orange orchards of Louisiana.

In corn, cotton, and sugar-cane fields the Argentine ant when present is constantly attending the aphids and mealy bugs, increasing the numbers of these species to an alarming degree, much to the detriment of the plants. The writer has determined that a considerable loss of sugar results from the attendance of the Argentine ant on the sugar-cane mealy bug.

HABITS.

Argentine ants are extremely social among their own kind, the individuals never having been observed to quarrel with one another, nor one colony with another. Workers may be carried for miles and placed with others of their kind and no apparent demonstrations of like or dislike are exhibited. The newcomers appear to enter into the colony spirit and are soon lost to the view of an observer. Any small nest will contain several queens which live together amicably.

The summer nest may be located anywhere—under sidewalks, under the sills of houses, in brick piles, stone piles, under a piece of board or a piece of tin, in an old tin can—in fact, in any place convenient to the food supply. In the winter months there is a tendency to concentrate into larger colonies, and they seek warm, dry, secure nesting places in which to hibernate. These desirable places are not plentiful, and where one is located the ants from some distance will seek its shelter. The winter is the most hazardous period of the year, for should a nest by any chance be flooded during a cold spell, when the ants are dormant, the chances of survival of the colony would be extremely slight. Usually throughout the latter part of December,

[1] Op. cit., p. 24.

January, and February (at New Orleans) these large colonies are found. They sometimes reach very extensive proportions and may contain several hundred queens and countless workers and immature stages. These colonies are usually located at the base of large trees on high, well-drained spots of ground, in manure piles, or in any other piles of decomposing rubbish where heat is generated. A warm day will make them particularly active, and they will form trails in all directions from these winter nests to food supplies. They may be observed traversing the trunks of trees every warm winter day, and from the trees trails are made to nearby houses, where they cause considerable annoyance.

With the advent of warm spring weather the breaking up of the large colonies occurs. This is the time of the year that food is very scarce, and at this season the ants are particularly aggressive and troublesome in the houses. *This is the best time to use poisoned sirup, which will be described later, for controlling this pest.*

LIFE HISTORY.

There are three adult forms to be found within a complete nest in the spring months of the year—the queen, the male, and the worker. A colony may be complete, however, with a queen and workers. Three immature forms are also present—the egg, larva, and pupa.

EGG.

In an artificial formicary a fertilized queen lays from 3 to 30 eggs per day when ample food is supplied. It is very probable that under natural conditions the egg production is considerably more. Only a few seconds are occupied for the laying of each egg. A worker, apparently awaiting the arrival of the egg, picks it up and transfers it to a pile of eggs already in the nest. The surface of the egg is somewhat mucilaginous and readily sticks to other eggs. This permits the workers to handle the eggs en masse and also permits of their being deposited in desirable locations on the walls and ceilings of the galleries.

The egg when first laid is about 0.3 mm. long and 0.2 mm. wide. It is elliptical, pearly white, lustrous, and without markings. As the time for hatching approaches the luster disappears. It is extremely difficult to detect the exact time of hatching. The average summer incubation period is about 15 days, but this, of course, is subject to the variations of temperature and humidity during this period.

LARVA.

The larva, when first hatched, is creamy white. Its body is very curved, but it gradually straightens as the larval growth continues. It is entirely helpless and is practically motionless.

The workers feed and cleanse the larvæ, moving them about with the fluctuations of temperature and humidity to the most desirable places within the nest. The full-grown worker larva is about 1.5 mm. long by 0.65 mm. wide. The average larval period throughout the summer months under normal conditions is about 13 days.

PUPA.

When the pupal stage is reached the sex of the individual is readily distinguishable. The pupa is white, with the exception of two distinct black eyespots on the sides of the head. The worker pupa is about 2 mm. long, the head and thorax being the larger part of it. The male pupa is about 50 per cent larger than the worker pupa, and the queen is still larger. The two latter forms may be readily distinguished from the worker pupa. The male pupa has a very large thorax and a small, closely coupled abdomen, while the queen pupa is much more symmetrical, the thorax is not so large, and the abdomen much larger than that of the male. The pedicel between the thorax and abdomen of the queen pupa is more constricted and elongated than in the male pupa.

After the first few days the color of the pupa gradually changes to creamy yellow and continues to darken until a light-brown color is reached just previous to emergence.

The duration of the pupal stage of the worker throughout the summer months averages about 13 days, while that of the male is about 22 days. No records have been established of the duration of the pupal period of the queen.

The pupæ of all the stages are aided in transformation by the workers. Upon first emerging the adult is of a light-brown color which gradually grows darker until the second day, when it becomes indistinguishable from other adults.

DEVELOPMENTAL PERIOD.

By compounding the average periods of development of the egg, larva, and pupa, a general average of 40 days results, which represents the complete development from egg to adult in the case of the worker and a somewhat longer period for the males and queens.

ADULT FORMS.

The worker is about 2.5 mm. in length and of a dark-brown color, and there is only one caste. The workers forage for food, attend the queen and the young, and fight to protect the colony. A large percentage of the workers stay within the nest at all times and are always ready for any emergency, whether it be to fight invaders or to hurriedly seize the immature stages and retreat to securer locations upon the slightest indications of rain or flood.

The workers are able to carry considerable liquid food in their abdomens, which become distended and transparent. This food is regurgitated when the nest is reached, and fed to the immature forms and other workers and queens in the nest. They are quite long lived and have been kept in artificial formicaries for many months at a time. It is quite possible that they may live a year under natural conditions.

The male is always winged. It is readily distinguished by its massive thorax, small head, and abdomen. It is about 3 mm. in length, and the body color is of a dark brown, the same shade as the worker. Males appear in the nest in the spring months of the year and gradually lessen in numbers as the summer advances.

When the queen first emerges she is winged, but at the time of copulation, or about that time, she loses her wings, and her activities from that time are devoted to egg producing. The deälated queen is about 6 mm. long and of the same color as males and workers. It is seldom that the queens leave the nest unless disturbed, but occasionally they may be seen crawling along an ant trail in company with the workers. At rare intervals they travel alone and may be observed wandering about aimlessly.

The queens have frequently been kept within artificial formicaries for more than a year, and it is reasonable to suppose that they will live much longer.

NATURAL CONTROL.

It would appear that heavy rains and resulting flood are the only factors of natural control of any great importance. They are especially effective if occurring during cold weather, for at this time the ants are sluggish and unable to exert themselves. Moderately cold weather does not appear to check their activities.

On November 18, 1911, a heavy infestation of this ant was discovered at Kosciusko, Miss., about half the town being infested. Residents stated that they had been troubled for about 7 years; several of them, owing to the great annoyance, had moved to parts of the town which were not then infested. On revisiting Kosciusko in April, 1912, the infestation had decreased to such an extent that it was quite difficult to find any of the ants. The meteorological records of the winter months revealed the following striking facts: The mean average temperature of the 6 months from November to April, inclusive, was 49.5°, but the rainfall for this period was excessive, reaching the total of 41.1 inches, whereas the average 10 years' precipitation for these months had been only 27 inches. This control was, however, only temporary. In June, 1915, Kosciusko was again visited and the ants were found to be very numerous and causing great annoyance to residents. The infestation had spread

over practically the whole town, as well as near-by corn and cotton fields.

During the same winter (1911–12) similar conditions were experienced at New Orleans, the winter months being accompanied by a rainfall of 41.56 inches, as compared to the 10-year average of but 26.1 inches. The numbers of ants were greatly reduced, the mortality probably being at least 70 per cent. The ability of this species to overcome such a catastrophe was well illustrated, for by September, 1912, the ants had apparently reached their maximum numbers.

REPRESSION.

OUTDOOR BARRIERS.

A number of experiments have been conducted to discover, if possible, an efficient outdoor barrier.

The sticky substance which is used in coating flypaper and is also sold in bulk for banding trees was effective for only a few days. The ants would carry particles of dirt and build a bridge over it. This substance, made much thinner than usual, as suggested by Mr. D. M. Rogers for use in the gipsy-moth work, was tried and with more successful results. Heavy bands 4 inches wide spread on two magnolia trees were effective for two months in the summer without having to be replenished or combed.[1]

In the cooler parts of the year these bands require frequent attention on account of the growth of mold on the surface. During wet weather in the winter in Louisiana this mold will form in a very few days, and the efficiency of the sticky band will be entirely destroyed.

It was found that 5 per cent of a carbolized oil added to the thinner preparation increased the effectiveness of the bands considerably and entirely prevented the growth of mold. The bands were also rendered more repellent and more resistant to winter conditions. A thin crust forms over the surface of the bands in the winter, but this is readily combed into the band in the spring and the band is as effective as ever. The crust on bands of the thinner preparation without the carbolized oil becomes too hard during the winter, and it is necessary to use fresh material in the spring. These bands were used on fig, magnolia, pecan, and orange trees and no injury to the trees was apparent. There is a possibility that the substance may be harmful to trees with a more tender bark, however.

To the thinner preparation were added in different tests 1 per cent of bichlorid of mercury, 2 per cent of nicotine sulphate, 10 per

[1] A wooden comb is supplied by the manufacturers for the purpose of combing the bands when a coating of dirt, insects, or any other foreign matter collects on the band. This foreign material is mixed in with a clean sticky substance, immediately under the surface of the band, and the band is as efficient as ever.

cent of naphthalene, and several other repellents. While bands containing bichlorid of mercury and nicotine sulphate were effective for slightly longer periods than the sticky substance alone, their use is hardly to be recommended.

INDOOR BARRIERS.

Perhaps the most effective and durable barrier which can be used indoors is a bichlorid-of-mercury tape or band. Tape is soaked in a saturated solution of bichlorid of mercury and then hung up to dry. It is then placed around the legs of tables, safes, etc., and if it is kept dry will last from six months to a year. Common lampwick one-half an inch wide is ideal for this purpose. After it has been treated in a saturated solution of bichlorid of mercury and dried, pieces are wrapped around the leg of the piece of furniture to be isolated and ends lapped over tightly and pinned. The tape can be readily renewed by another soaking in bichlorid of mercury and repinned in place.

Twenty-five per cent of bichlorid of mercury mixed in shellac may be painted around the legs of furniture, and when dry it will be quite as satisfactory as the tape.

Extreme caution is advised in handling bichlorid of mercury, as there is always an element of danger in using this poison. In recent years the sale of this drug to the layman has been practically discontinued.

A simple and efficient, though perhaps unsightly, barrier may be made by placing the legs of furniture in saucers and putting a generous supply of moth balls in each saucer. The moth balls will slowly volatilize, and it is necessary to add more from time to time, but the ants will not cross the barrier thus formed.

Coal oil placed in saucers in which the legs of furniture rest will repel the ant, but the odor of the oil is disagreeable to most persons.

ANT POISONS.

Many and varied experiments have proved that it is futile to try to exterminate Argentine ants with a poison which kills rapidly. A few workers may be killed, but the masses of ants will quickly recognize the source of fatality and avoid the "doctored" food. The few workers killed in this way will have no effect in reducing the numbers. None of this poison will reach the queens in the nest, and it has been found that it is essential to kill off the queens in order to prevent further multiplication of the pest.

Soon after the writer took up the work on the Argentine ant Mr. L. J. Nickels[1] published an article on the control of the Argentine ant in California, in which a rather successful poisoned sirup was described. It was decided to give this poisoned sirup a thorough trial

[1] Nickels, L. J. Field Work in the Control of the Argentine Ant. Jour. Econ. Ent., v. 4, no. 4, pp. 353–358. 1911.

in the Southern States. The following experiment is based on Mr. Nickels's recommendations:

EXPERIMENT AT HATTIESBURG, MISS.

At Hattiesburg, Miss., an infestation of 8 blocks was found to be an ideal place for this experiment.

The following buildings were located within the infestation: Thirty-eight residences, 7 stores, 2 meat markets, 2 small hotels, 2 restaurants, 2 bottling establishments (which will be designated hereafter as establishment A and establishment B), a laundry, a marble factory, a sawmill and office, and a church.

Thirty dozen 1-pint fruit jars were prepared in the manner outlined by Mr. Nickels. The porcelain was broken out of the metal tops and five holes about three-eighths inch in diameter were punched near the center of each top. Sponges were cut up into pieces and a piece inserted in each jar. The piece of sponge filled about a third of the space in the jar.

A gill of the poisoned sirup was put into each jar. On each jar was pasted a poison label.

On September 28, 25 dozen of these jars were distributed—about six jars placed in each house and store. Two vacant blocks were not covered at this time, but on November 16, 3 dozen jars were distributed on these blocks. As the jars had to be placed outdoors, they were laid on one side to prevent rain from entering. The residents of the other blocks were questioned as to results, and they reported very favorably. In most cases the ants had become much less abundant. The two meat markets had fewer ants than before, but the sirup rooms of both bottling establishments were as badly infested as ever, the ants evidently preferring the flavored sirups to the poisoned sirup.

In the latter part of April, 1912, the infestation was again determined. This was immediately after the winter previously referred to, when the infestation had been so reduced at Kosciusko and New Orleans. Though the numbers of ants had certainly been reduced in Hattiesburg, they were still present in proportionately greater numbers than in New Orleans. It is likely that the better wintering facilities at Hattiesburg were due particularly to excellent drainage and the presence of numerous trees.

On June 18 another inspection was made. The numbers of ants were at this time about 60 per cent of what they were during the previous November. The eastern line of infestation had not been extended and the ants were giving little trouble in the houses, though they had apparently concentrated around the sirup rooms of both bottling establishments. The stores and meat markets had not been troubled to any extent, but there were many trails of ants on the trees. Many of the jars were examined, and it was found that a de-

composition had taken place in the sirup in the jars, a very disagreeable odor being given off. As many of the jars as could be found were collected. These were thoroughly cleaned, especially the sponges, which were washed in boiling water. Fresh sirup was prepared and the jars recharged and again distributed.

The jars were again recharged in October. At this time, though the infestation had not spread, the ants were more numerous. They were very numerous in the sirup rooms of both bottling establishments, and in both meat markets.

Observations were made in December, and at this time conditions were fairly satisfactory. Ants had troubled only two of the houses, in each instance only for a day or so, and had then left. The bottling establishments were closed for the winter. The intention was to recharge the jars at this time, but the status was so satisfactory that it was decided to leave them until the following spring.

In the beginning of April the ants were not very plentiful. Only three houses had been invaded during the winter. The sirup rooms of both bottling works were again besieged.

By the latter part of May the ants were more numerous all over the infested area, though none of the residents or storekeepers had so far been troubled. The proprietor of bottling establishment A now had his sirups isolated and the ants were noticeably fewer around this building, but they were in increased numbers around the other plant. The ants were now very numerous on one block, and as the jars had not been satisfactory outdoors, special paraffin-covered rainproof paper bags were prepared to place on the trees near the houses and along the streets throughout the infested area. The experiment had been conducted for 20 months and the results had not been entirely satisfactory. The ants had been almost completely kept out of the houses and stores, except the sirup rooms of the bottling works, but large numbers were still present outdoors.

It is fairly conclusive that the sirup within the houses repelled the ants, for even in the spring the ants gave little trouble to the residents.

On July 9, 50 paper bags[1] containing this sirup were placed on trees throughout the infested area. About half of these bags were placed on trees in one block. All the bags were tacked about 15 feet above the ground to keep them out of reach of children and to arrest evaporation as much as possible, bags at this height being in the shade.

On August 13 a status inspection was made, and very remarkable results were observed. There were not at this time more than 20 per cent of the ants on the trees as compared with July, and all of the houses without exception situated anywhere near the trees had

[1] A description of the preparation of this bag is given on pages 20 and 21.

been invaded. None of the stores along Bay Street, near which were no trees, had been bothered by the ants. All the jars were recharged.

In November conditions were very satisfactory. Comparatively few ants were to be seen, and these were mostly on the trees. No ants were to be found in the sirup room of bottling establishment A, and there were very few in the vicinity of the building. There were very few ants on the trees in one block. By far the largest number of ants were to be found around the building in which bottling establishment B had been located. People in the house next to this building were being considerably troubled.

In January, 1914, all the jars were recharged and 150 paper bags containing the poisoned sirup were distributed over the infested area.

On April 7 a thorough inspection was made, and the numbers of ants were found to be greatly reduced. Nowhere had the ants caused any annoyance. There were very few ants on any of the trees. In several places native ants had again taken up their abode within the infested area, indicating that the Argentine species was dying out.

In the latter part of May the jars were recharged and 300 poison bags placed in suitable locations. An inspection at that date proved that the experiment was continuing very satisfactorily.

Native ant nests could be found dotted over the whole area. The largest number of Argentine ants was found around the abandoned building of bottling establishment B; in fact, this was the only place where the ant could be found in large numbers.

An inspection on June 29 indicated that the experiment was progressing favorably. The numbers of Argentine ants around bottling establishment B had greatly decreased, it being actually difficult to find them on these premises. Not a vestige of the infestation could be found on three of the blocks.

In mid-September the territory was again inspected. The conditions were found to be excellent. Scarcely an Argentine ant could be seen in any part of the once-infested territory.

Everyone living in the formerly infested area was of the opinion that the Argentine ants had been completely eradicated, but the writer found a few workers. However, he decided to consider the experiment concluded, for the time at least. It was possible that the queens were all destroyed and that just a few workers remained. There was also the possibility of the native ants finally exterminating the Argentine species.

The poisoned sirup had finally proved efficient, though it must be stated that it was necessary to expose it both indoors and out.

IMPROVEMENT OF THE NICKELS SIRUP.

In the tests with the Nickels sirup a number of objectionable features were encountered which finally led to the preparation of a

greatly modified sirup. In all the experiments the sirup proved very attractive and palatable to the ants at first, but their visits gradually decreased until the sirup was avoided, although in some instances the trails continued to pass by the poison jars. The period of attendance at the sirup varied somewhat with the seasons, being longer in winter. Even in the winter, however, a repellent action was apparent. In preparing the solution it had been noticed that the sirup turned brown, becoming darker the longer it was boiled, although it was made in a pail which in turn was placed in a bath to prevent burning.

Another objection was the crystallization of the sirup to a greater or less extent upon cooling. On the advice of a sugar chemist the proportion of water was increased to make a saturated sugar solution; 10 pounds of water to 20 pounds of sugar and 1 ounce of sodium arsenite were used. The Nickels sirup contained one-fourth per cent arsenic, while this more dilute sirup contained one-fifth per cent, but the dilute sirup was quite effective. With the exception of the first application, the dilute sirup was used throughout the length of the Hattiesburg experiment. Crystallization of from 5 to 15 per cent of the weight of sirup still occurred in short periods, but as high as 50 per cent when the sirup had been in the jars for several months. This of course had the effect of proportionally increasing the percentage of poison in the liquid and consequently its repellent power. Newly made sirup appeared to be less repellent than that which had stood for several weeks.

The repellent action of the sirup is illustrated by an experiment conducted in a private residence, which was badly overrun with ants. The ants were abundant in the refrigerator, safe, and sink, and literally covered the floors. Six fruit jars containing the Nickels sirup and sponges were placed in different rooms in the house, and 6 paraffined paper bags containing the same sirup and a sponge were placed around the house outdoors on trees, fence, and back porch. The sirup was about a month old. The experiment was begun at 1 p. m. At 5 p. m. hardly an ant was to be seen in the house, although a few were to be found at each jar and many were visiting the bags. Two days later not an ant could be found in the house and only three of the bags were attended by ants. As it seemed impossible that the colonies could have been exterminated so quickly, the adjacent vacant lot was inspected. This lot was overgrown with weeds, and in a corner near the house there was a pile of old lumber. Ants were found in abundance nesting in the lumber, and many were present wherever they could find dry quarters in the lot. It was quite evident that the ants had been repelled by the poison.

A series of experiments to obtain definite data on the repellent properties of the sirup were conducted in the Horticultural Hall,

Audubon Park, New Orleans, with the Nickels sirup in the strength as recommended originally, and also double, half, and quarter strengths. One gill of sirup was used to a jar, each jar being placed on its side to give free access to the ants, to prevent the entrance of water, and to prevent mold. The "Hall" furnished ideal conditions for the experiment, the temperature throughout the year being kept high and uniform. The abundance of various species of scale insects and aphids attracted the ants in great numbers at all seasons, but especially in cold and wet weather. Three jars of each strength were used and observations were made frequently for a period of 32 days. At the time of this experiment the ants were very numerous, due to the extremely wet summer of 1912. The rate of attendance and relative repellent value of the four strengths of the poison are shown graphically in the first part of Table I.

TABLE I.—*Experiments with sodium arsenite ($NaAsO_2$) added (in four strengths[1]) to sugar sirup solution, 1912.*

[Symbols: A=Heavily visited by ants. B=Only attended by a few ants. C=Not attended by ants.]

FIRST TEST, IN HORTICULTURAL HALL.

Date.	Double strength.			Nickels solution.			Half strength.			Quarter strength		
June 8	A	A	A	A	A	A	A	A	A	A	A	A
June 10	A	B	A	B	A	A	A	A	A	A	A	A
June 12	B	B	B	B	A	A	A	A	A	A	A	A
June 13	A	B	A	A	A	A	A	A	A	B	A	A
June 14	B	C	B	B	A	A	A	A	B	A	A	A
June 15	B	C	A	A	A	A	A	A	A	A	A	A
June 17	B	A	A	A	A	A	A	B	A	C	A	A
June 19	A	B	B	A	A	A	A	A	A	A	A	A
June 21	B	B	A	A	A	A	A	A	A	A	A	A
June 22	B	A	A	C	A	A	A	A	A	A	A	A
June 26	A	C	B	B	C	C	A	A	C	C	A	A
June 28	C	C	A	C	A	B	A	C	A	C	A	A
July 1	B	A	B	C	A	C	A	C	A	C	A	A
July 2	C	B	C	C	A	C	A	A	C	C	A	B
July 5	C	B	C	C	C	A	A	B	A	C	A	A
July 8	C	C	C	C	C	A	A	A	C	C	A	A
July 10	C	C	C	C	C	A	A	B	A	A	C	A

DUPLICATE EXPERIMENT, USING PAPER-BAG SIRUP CONTAINERS TACKED ON FIG TREES (OUTDOORS).

July 26	A	A	C	A	A	B	A	A	A	A	C	A
July 28	B	B	C	B	B	B	A	A	B	A	A	A
July 29	A	A	B	B	A	A	A	A	A	A	A	A
July 30	A	B	C	C	A	A	A	A	B	A	A	A
July 31	C	B	C	B	A	B	A	A	A	A	A	A
August 1	C	A	C	B	B	A	A	A	A	A	A	A
August 2	C	C	C	C	B	A	A	A	A	A	A	A
August 3	B	C	C	A	A	A	A	A	A	A	A	A
August 5	A	A	C	A	B	B	A	B	A	A	A	A
August 12	A	A	C	A	A	A	A	A	A	A	B	A
August 14	B	B	C	A	A	A	A	A	A	A	A	A
August 16	B	C	A	A	A	B	A	A	A	A	A	A
August 19	B	B	C	A	B	B	A	A	A	A	A	A
August 21	C	C	B	B	A	C	A	A	B	A	A	A
August 23	B	C	C	A	A	B	A	B	A	A	B	A
August 26	A	C	B	A	A	A	A	B	A	A	A	A
August 29	A	B	C	A	B	C	A	A	B	A	A	A
August 31	A	A	C	A	B	B	A	B	A	A	A	A

[1] Double strength——10 pounds granulated sugar + 5 pounds H_2O + 1 ounce $NaAsO_2$.
Nickels solution——10 pounds granulated sugar + 5 pounds H_2O + ½ ounce $NaAsO_2$.
Half strength——10 pounds granulated sugar + 5 pounds H_2O + ¼ ounce $NaAsO_2$.
Quarter strength——10 pounds granulated sugar + 5 pounds H_2O + ⅛ ounce $NaAsO_2$.

The experiment was duplicated, except that the sirups were placed in waxed paper bags tacked on fig trees. These bags each held a gill of sirup, and sponges were placed in the sirup to allow easy access of the ants. At the time of conducting the experiment the figs were ripening and the ants were visiting the trees in immense numbers. It will be seen from the second part of Table I that the results were substantially the same as in the indoor experiments. The two experiments may be summarized as follows:

The most concentrated sirup (2 ounces sodium arsenite) attracted great numbers of ants in only 32 counts, few ants in 34 counts, and no ants whatever in 39 counts.

The standard Nickels sirup (1 ounce sodium arsenite) attracted great numbers in 62 counts, few ants in 25 counts, and no ants in 18 counts.

The half-strength solution ($\frac{1}{2}$ ounce sodium arsenite) attracted great numbers in 88 counts, few ants in 12 counts, and no ants in 5 counts.

The quarter-strength solution ($\frac{1}{4}$ ounce sodium arsenite) attracted great numbers in 92 counts, few ants in 4 counts, and no ants in 9 counts.

The experiments prove, therefore, that the excessive quantities of the arsenic in a sirup will cause it to become repellent. The observations also indicate that the sirup decomposed more rapidly as the amount of the sodium arsenite increased.

Dr. W. E. Cross, research chemist of the sugar experiment station at Audubon Park, was consulted with regard to the various defects in the Nickels sirup. His explanations and suggestions, which were of great importance in the further conduct of the investigations, are given below.

When granulated sugar (or sucrose) is heated, it is partially changed to invert sugar (or glucose), and if to this is added sodium arsenite, which has an alkaline reaction, chemical decomposition takes place. When heated this reaction is hastened and the compound becomes darker and darker. On account of the instability of the sirup, it will further decompose on standing and the final product will be a substance with an unpleasant odor and taste. The addition of a small quantity of tartaric acid to the sugar sirup before adding the sodium arsenite will produce a greater inversion of the sucrose, thus lessening the danger of crystallization, and will neutralize the alkalinity of the sodium arsenite, preventing decomposition. If a slight acid reaction is obtained the sirup will keep indefinitely. The inversion of the sucrose reduces the sweetness of the sirup, and to balance this 7 per cent of pure honey is added.

The preparation finally proposed by Dr. Cross is made as follows:

Prepare a sirup:

Granulated sugar	pounds	15
Water	pints	7
Tartaric acid (crystallized)[1]	ounce	¼

Boil for 30 minutes. Allow to cool.

Dissolve sodium arsenite (C. P.)	ounce	¾
In hot water	pint	1

Cool.[2] Add poison solution to sirup and stir well. Add to the poisoned sirup:

Honey	pounds	1½

Mix thoroughly.

On April 23, 1914, Dr. Cross and the writer prepared two sirups of the above formula (exclusive of the honey, which only makes the sirup more palatable), except that one lacked the tartaric acid. After cooling, they were tested in a refractometer, with the following results:

Sirup with tartaric acid, specific gravity 1.339, Brix (sugar content) 68.8.
Sirup without tartartic acid (Nickels sirup), specific gravity 1.343, Brix 68.05.

The Nickels sirup had lost 0.75 per cent of its sugar content and was of a very dark brown color. The new sirup was bright yellow (amber color), clear, and transparent. Equal samples of each were placed in quart exhibit jars with ground-glass stoppers, labeled, and set aside. A second reading was made on June 20, 1914, as follows:

Sirup with tartaric acid, specific gravity 1.340, Brix 68.40.
Nickels sirup, specific gravity 1.3321, Brix 67.01.

The new sirup had lost 0.4 per cent of its total solids and had not noticeably changed in color or sweetness. The Nickels sirup had lost 1.04 per cent of its total solids, was nearly black, partly crystallized, and had lost much of its sweetness. In the beginning of August the stoppers were removed and cheesecloth tied over the mouths of both jars, to find how evaporation would affect these sirups. The jars were placed on a shelf in the laboratory. In the beginning of January, five months after the jars were first left open, they were examined. Figure 2 shows the conditions. The difference in the quantity of the sirups, in color, and in the crystallization that had taken place within the jar containing the Nickels sirup may readily be noted. A reading was taken of these sirups, as follows:

Sirup with tartaric acid, specific gravity 1.385, Brix 75.48.
Nickels sirup, 1.367, Brix 72.68.

[1] In the first experiments one-half ounce of tartaric acid was used, but this is found unnecessary.

[2] In earlier experiments the sirup was boiled 30 minutes after addition of the poison, but boiling will raise the "Brix" (total solids), which is to the disadvantage of the sirup as an ant bait.

The Nickels sirup[1] was then drained from its jar and was found to weigh 160 grams. The jar and crystals were then weighed, the crystals dissolved out of the jar, and the weight of the jar subtracted from the total weight of the jar and crystals. It was found that 333 grams of sugar crystals were present.

	Grams.
Weight of sirup when first made	660.23
Weight of sirup remaining + sugar crystals	493.00
Water passed off by evaporation	167.23

The 660.23 grams of sirup contained 1.333 grams of sodium arsenite with a poison content of 0.202 per cent.

The 160 grams of sirup remaining contained 1.333 grams of sodium arsenite. The poison content was now 0.836 per cent.

The sirup with tartaric acid had a small precipitation. As the Brix had been raised 7.4 per cent through evaporation, the poison content was very slightly raised. This sirup now weighed 643.35 grams, the color and sweetness being still quite stable.

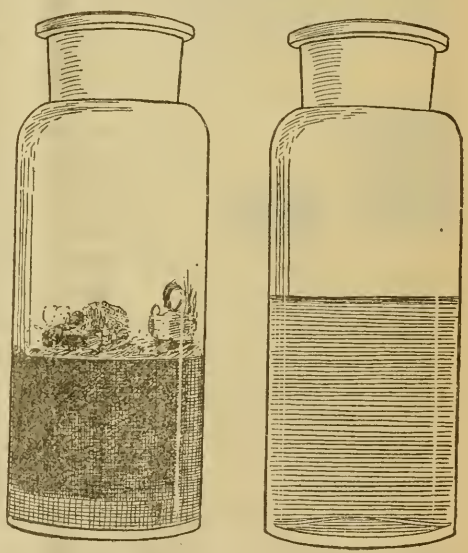

FIG. 2.—Comparison of the improved sirup (right) with the Nickels sirup (left), showing the amount of sirup left in each and the amount of sugar in the Nickels sirup. (Original.)

Immediately after preparing these two sirups, April 23, 1914, 2 fruit jars of each, containing 1½ gills of sirup apiece (without honey), were set out along heavy ant trails in the Horticultural Hall. Absolutely clean and odorless sponges were used.

For the first 4 days the ants showed a preference for the old type of sirup (without the tartaric acid) but for the next 21 days they showed no preference. Then one jar of the old sirup was abandoned. This proved to be partially decomposed. On moving to another spot it was attended for 10 days more, then abandoned completely. Thus for a total of 35 days this jar attracted the ants. Seven days later the other jar of this sirup was abandoned and no matter where placed neither jar had any attraction for the ants.

[1] Figure 3 shows the small quantity of sirup that still remained, as well as the large bulk of sugar crystals which had formed in the jar. The jar containing the acidified sirup is placed at the side for comparison.

The jars with the new type of sirup were visited constantly for 62 days, or to the conclusion of the experiment. The small amount of sirup left was still clean and as sweet as at first.

Tests of the poisonous qualities of both liquids were made with colonies in Janet cages, under control as to food. There was practically no difference in toxicity. Workers in both cages began to die in 4 days, the queens stopped ovipositing in 14 days, and winged males died very quickly, the queens in 17 days, and the whole colony in each case was exterminated on the thirty-second day.

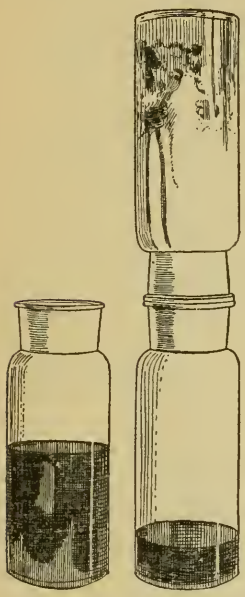

FIG. 3.—Comparison of the improved sirup (left) with the Nickels sirup (right) after five months' evaporation. The improved sirup is still clear and sweet, while the Nickels sirup is dark and full of crystals and decayed matter. (Original.)

PRACTICAL TESTS OF THE IMPROVED SIRUP.

The new sirup, made exactly as in the formula given above, is very palatable to the ants at any season of the year. It was found that containers charged with it placed at selected points outside a residence would attract the ants and they would cease to invade the house. A private residence in a large plot of ground on a street corner with a row of large oak trees along each street was heavily infested with ants, which were to be found in the sink, the refrigerator, all over the floors, etc. On June 18, 6 cans each containing this sirup and a sponge were hung on the brick pillars which supported the house. The following morning there was scarcely an ant to be seen in the house and the ants were attending the sirup in large numbers. The same conditions existed throughout the length of the experiment, which was terminated on August 10. Many such small experiments have been conducted, the results being equally successful.

APPLICATION OF THE SIRUP.

The paraffin-covered paper bag[1] shown in figure 4 is undoubtedly the cheapest container. It can be made in large quantities at a cost of about $5 per thousand. Small 1-pound bags used in grocery stores are obtained, and two or three holes about one-fourth inch in diameter are cut through each folded bag with a leather-punch or similar instrument. This provides each bag with two holes on each side for the entrance of the ants. Being opened, the bags are dipped in a pan of molten

[1] The writer is indebted to Mr. R. W. Moreland, Bureau of Entomology, for his suggestions in the preparation of this waterproof container.

paraffin and set aside to dry. The paraffin, forming a waterproof surface, materially lengthens the life of the bag, which is protected from the entrance of water through the holes by part of another (2-pound) paraffined bag which covers the first one like a canopy. In use, each bag is provided with a small quantity of poisoned sirup and a piece of sponge, the protecting outer piece of bag is drawn up over it, and the ends of both are folded over at the top and tacked to a tree. On account of the bag coming together at the top it is very narrow at the point where the entrance holes are made; consequently very small pieces of sponge are required. The bags have been known to last for long periods, but the larger percentage of them last only about 2 or 3 months. They can not be recharged.

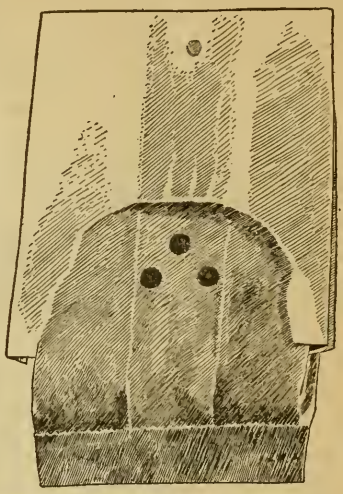

FIG. 4.—Paraffined paper bags arranged as a container for ant poison sirup. The apron has been cut away to show the ant entrance holes. Such bags are nailed to trees. (Original.)

The tin can shown in figure 5 is the most satisfactory container. Any sized can may be used, but the handiest size is the one-half pound baking-powder can. The can must have a friction cover, and of course it must hold water. If the can is indented deeply on the two opposite sides (as illustrated in the drawing, fig. 5) and the cover replaced, it will be observable that there is ample space between the top of the can and the cover for the entrance of the ants, and the can, if kept in an upright position, will be weatherproof. About a gill of the sirup will be sufficient for several months, but in heavy infestations it is better to put 2 gills in each can. It is very advisable to place a fairly large piece of sponge in the can. The sponge will float on the sirup and allow the ants to feed in large numbers. A piece of wire about 6 inches long may be bent for a handle, a hook inward at each end being made. The hooks may be attached under the lid of the can where it projects over the part that has been indented. This forms a handle by which

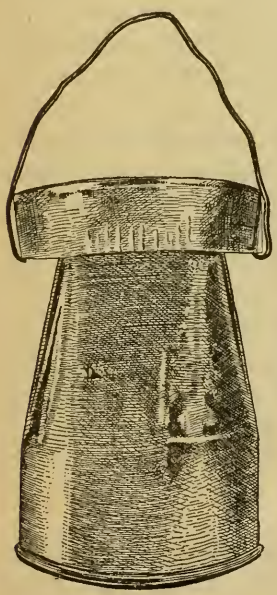

FIG. 5.—Tin can container for ant-poison sirups used in outdoor experiments. (Original.)

the cans may be hung on trees, fences, walls of houses, etc. The ants prefer to climb for their food, and it is well to hang the cans near ant trails going up trees, walls, etc. It is advisable to hang the cans in the shade to prevent the evaporation of the sirup, for though it has been proved that evaporation does not affect this sirup to a marked extent, it is well to avoid raising the solid contents of the liquid. Eight to ten of these cans should be sufficient to place around an ordinary city house and lot. If the grounds are large and if many trees are present, more cans should be placed out.

From the results so far obtained, the careful preparation of the poisoned sirup can not be too highly emphasized. Very accurate balances are necessary for the weighing out of the poison and the tartaric acid. This is especially true when small quantities of the sirup are prepared.

PLANS FOR MUNICIPAL CONTROL WORK.

In effecting control in towns and cities it is first necessary to ascertain the extent of the infestation. This should be mapped out so that workmen in distributing the cans will be able to refer to the map to insure the covering of the entire territory. Cans may be obtained at wholesale at about $16 per thousand. About 10 pounds of "grass" sponges will be required per 1,000 cans. These will cost about 75 cents per pound. The sponges should be thoroughly washed and dried before use. When wet they may easily be torn into pieces about 2 by 2 inches. Using 1 gill of sirup per can, 200 pounds of granulated sugar will be required per 1,000 cans. The cost of the sodium arsenite is about 80 cents per pound, and 1 pound will be sufficient for 1,500 cans. Tartaric acid (crystallized) costs about 70 cents a pound, which will be enough for 4,500 cans. From 60 to 100 cans will be required per block, depending on the size of the block. The late fall, winter, and spring are the most desirable times in which to do this work, as in these seasons the natural food is least plentiful and the ants most hungry. Two men should be able to prepare the sirup, wash and tear up the sponges, and charge about 2,000 cans per day and distribute about 1,000 cans per day.

TRAPPING ANTS.

By taking advantage of their winter colonizing habit the ants may be attracted in large numbers to specially prepared trap boxes, which may be fumigated when large numbers have gathered in these boxes for winter nesting. Newell and Barber, who originated this method of control, describe in Bureau of Entomology Bulletin 122 some very interesting and successful trap-box experiments. The boxes were filled with decaying vegetation, the heat generated making them very attractive as hibernating quarters. Carbon bisulphid was found to

be the best and most economical fumigant for use in the trap boxes. It is hardly necessary to state that this method of control is not applicable to city conditions, where dry nesting quarters are very plentiful and the ants do not colonize to any great extent.

SUMMARY OF CONTROL MEASURES.

ANT BARRIERS.

In grossly infested houses much relief may be secured by isolating tables, refrigerators, safes, beds, etc., with bichlorid-of-mercury tape, or by placing the legs of articles of furniture in saucers filled with moth balls or coal oil. Trees, beehive stands, and other outdoor objects may be isolated with the sticky substance used on fly paper but made thinner than usual. If 5 per cent of carbolized oil be added, the durability of the bands will be considerably increased.

REPELLENT ANT POISONS.

Repellents are much used to keep the ants from buildings. Strong antimony or arsenical sirups, a number of which are sold by druggists in infested territory, are used for this purpose. They give quick relief for short periods, but they are not a factor in the reduction of the infestation.

ATTRACTIVE ANT POISONS.

The only effective poisons yet known for permanent control are poisoned sirups. The improved arsenical sirup recommended on page 18 will not spoil and is superior to any other formula yet tested on account of its stability at high temperatures, freedom from crystallization, and continued attractiveness.

TRAPPING ANTS.

Trapping ants may be accomplished in rural locations by providing boxes of decaying vegetation in the winter. The colonies will move into these boxes and the ants may then be killed with carbon bisulphid.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 382

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. ▲ July 8, 1916

COTTON BOLL-WEEVIL CONTROL IN THE MISSISSIPPI DELTA, WITH SPECIAL REFERENCE TO SQUARE PICKING AND WEEVIL PICKING.

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INTRODUCTION.

In devising measures for the control of the boll weevil the experience of the Bureau of Entomology has shown that those which are practicable in one region do not necessarily apply in another. The conditions vary according to climate, topography, and systems of agriculture. Each locality offers peculiar conditions, but striking differences occur between the cotton regions of Texas and of the delta of Louisiana and Mississippi. These varying conditions have led to the development of rather distinct methods of control of the weevil, as applied to these two regions.

During the progress of the Mexican cotton boll weevil northward and eastward across the State of Texas, a combination of control measures which was reasonably effective in limiting the damage to the cotton crop was devised and adopted. These measures were largely of a more or less indirect nature, such as planting early maturing varieties, frequent shallow cultivation, wide spacing of the plants to allow the sunshine to reach the fallen squares, etc. Largely owing to the comparatively dry climate and the exceedingly high mortality of the weevil stages in the fallen forms, produced by the hot sunshine, these measures generally sufficed for that region. When the weevils invaded the Delta region of the Mississippi River, in the States of Louisiana and Mississippi, however, it was found that weevil control was complicated by new conditions. The extremely heavy rainfall and high humidity prevailing in the Delta region, together with the rank vegetative growth typical of the cotton plants there, combined to reduce greatly the most important factor in the

Note.—This bulletin is intended to give practical advice to the cotton raisers of the Mississippi Delta on the subject of controlling the boll weevil.

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natural control of the weevil, namely, the mortality produced by heat in these fallen forms. The ground remained so moist between the rows in many fields for considerable periods that the weevils were able to mature under the most favorable conditions and consequently to multiply prolifically.

To meet these new conditions various direct control measures have been devised and practiced. The most popular of these consisted of the collection of the overwintered weevils from the plants in the spring and the gathering and destruction of the fallen infested forms from the ground. These operations are commonly termed "weevil picking" and "square picking," respectively. They are based on the fact that the most critical period in the yearly cycle of the weevil and the time at which its numbers reach the lowest ebb is in the spring when the comparatively few survivors of the winter are emerging. In an average season these overwintered weevils are relatively scarce, and it is not until their progeny begin to mature and multiply that the actual severe damage to the cotton is produced. Owing to the very high fecundity of the individual females, each overwintered weevil destroyed early in the spring means the elimination of an enormous number of potential progeny in the later generations, and, in the same way, the collection of the immature stages of the weevils of the first-bred generation in the fallen forms not only reduces the weevil abundance by the actual number collected but also retards further multiplication. Because of these facts a number of cotton planters have considered it a paying proposition to incur a considerable expense per acre to destroy these early weevils. It was found, however, that the results secured by the different planters practicing these control measures varied widely and their conclusions as to the actual benefit derived were equally diverse. Many claimed very positive gains while many of their neighbors operating under much the same conditions could see no benefit from the measures and considered the expense thus incurred an absolute loss.

Another factor enters into the problem and further complicates matters. This is the question of labor supply. Under the conditions at present prevailing in the Delta the available labor, during the months of May and June, is always more or less short of the labor needed. In addition to this, one very important effect of the weevil on the economic system of this region has been the forcing of diversified farming instead of the old one-crop system. The new crops most generally adopted were corn and oats. As a result the labor crisis during the spring period has become even more acute. Not only does the cotton require cultivating and hoeing, but it is also necessary to cultivate and hoe the corn and cut, shock, haul, and thrash the oats

during this same period. None of these operations could be neglected without a serious loss to the plantation. As these all fall at the time when it is necessary to perform the weevil-picking or square-picking operations it has become more and more necessary to determine the actual benefit derived from these control measures and to ascertain to what extent it would be profitable to slight the other operations in their favor. A series of studies was, therefore, inaugurated at the Delta Laboratory located at Tallulah, La., in the effort to secure definite information on these points. These studies were largely conducted on an experimental basis, but their results were checked by observations on the plantation use of the different control measures. The following is a brief consideration of the points brought out by these studies.

SQUARE PICKING.

The first of the studies consisted of plat tests on the effect of picking only the fallen forms during the spring. The first picking was made as soon as the fallen forms had reached a considerable number and still before the weevils had started to emerge from them. As the emergence of the weevil from hibernation was exceedingly late during the season when this test was conducted (1915), it did not prove necessary to conduct this first picking until June 16. Of course this date of picking would vary widely with the season, and in a year of normal emergence it would undoubtedly be much earlier. Following this the plat was carefully picked over every 7 days until July 14, a total of five pickings, extending over a period of 28 days. During this time 42,672 forms per acre were collected. In actual bulk this equaled about 42 gallons per acre. The method of picking used was the simplest possible. Mixed negro laborers were provided with sacks for holding the forms and were sent down the rows to gather all forms from the ground by hand. The picking was carefully supervised in order to make sure that the collections were thorough.

The weevil infestation in these plats was followed carefully throughout the season and it was soon found that the infestation in the picked plat was showing a very decided effect from the operation. For example, on July 6, 18 per cent of the squares in the picked plat were infested, while 44 per cent were infested in the untreated check plat. On July 13, the percentages were 37 and 63, respectively. In fact all observations consistently demonstrated that the square collection was reducing the weevil infestation within the treated plat. Of course the final criterion determining the effect of the operation was the production, and it was found that the picked plat produced 23 per cent more seed cotton per acre than the check. However, this

gain in yield must not be considered as being net profit, since there are certain expenses to be charged against the value of this increased production. These are the actual labor involved in the control operation and the effect of diverting the labor from the usual operations to those of weevil control.

Careful studies were made on the labor involved in these square pickings and the figures secured from the experimental tests were also checked under conditions more closely approximating those of plantations. From these studies it was found that the average labor per acre involved in the pickings ranged from about 4 hours for the first to about 24 hours for the fifth. The general average of all the pickings was slightly over 11 hours per acre per picking. As the labor day in the Delta section is usually of about 12 hours during the spring, this indicates that the pickings would average about 1 day's labor per acre, or a total of 5 days for the five pickings. As the greater part of the picking is done by women and children, this labor probably has a value of not more than 50 cents per day on the average. This would make the five pickings cost about $2.50 per acre on a wage basis. Of course this labor will vary greatly with the locality, field, and seasonal conditions, as these factors will determine the number of fallen forms present to be picked. Heavy infestation, producing a large number of fallen infested forms, will, of course, require much more labor per acre to control, while a lighter infestation, particularly on thin, sandy land, where the square formation is not so profuse, will result in comparatively few forms to be collected, and the labor required will be lessened. Under certain conditions of soil and climate there is frequently a very heavy shedding of uninjured forms. Of course these can not be distinguished from the infested forms when on the ground, and must be gathered. This condition occasionally becomes so pronounced that it greatly increases the labor involved in picking.

The time interval between pickings in this test (7 days) was selected arbitrarily, but it is probably about the most satisfactory period. This gives an interval sufficiently short to prevent any considerable weevil emergence from the fallen forms between pickings and is still about as long as can be safely allowed. The number of pickings must depend entirely on the conditions prevailing. The object of the number utilized in this test was to cover the period from the first falling of squares in considerable numbers to the time when the work becomes too bulky to handle. As previously mentioned, in an ordinary year the operation would probably start earlier than was necessary in 1915, but, owing to the rapid increase in the labor required during the later pickings, it would probably not be profitable to give more than four pickings under ordinary

conditions. If any benefit is going to be derived, it should be secured during this period, and the cost of the operation will be sufficiently low to allow a reasonable margin for profit. It seems hopeless to expect to prevent all weevil multiplication in the field, regardless of how thoroughly the picking operations are conducted, and the best that can be hoped for is to retard the time when the practically complete infestation of squares is reached, thus allowing a slightly longer period for the formation of fruit and the safe maturing of the bolls which have already been set.

The disposal of these infested forms is an important item. Based on the conditions which prevailed in the more western territory, where the parasitic control of the weevil is a considerable item and where smaller amounts of forms are collected, it was recommended that they be placed in screen cages, instead of actually destroying them, thus allowing the emergence and escape of the weevil parasites in these forms and still retaining for later destruction the weevils maturing from them. In the Delta, however, the conditions are so different that this recommendation is not advisable. Parasitic control of the weevil in the Delta is generally so low that it is of little importance, and therefore comparatively few parasites would be saved by this means. In fact, unless rather elaborate and expensive precautions were taken to prevent the weevils' escape from these cages it seems probable that a sufficient number of weevils would be released to more than offset the parasites saved. This consideration is further emphasized by the carelessness of the negro laborer. In addition, the quantity of forms handled in the Delta is so great that the expense of providing cages for their disposal is practically prohibitive. It has already been shown that in the plat tests of 1915 an average of 42 gallons of forms were collected per acre. When it is considered that many of the Delta planters reckon their cotton acres by the hundreds and even by the thousands, it is easy to see what an enormous task it would be to provide screen cages for these forms. In view of these facts it seems advisable to dispose of these forms in the quickest and most effective manner possible. This may be done quite easily by burning or burying them.

WEEVIL PICKING.

There are a number of different methods of collecting the adult weevils from the cotton, but it is probably best to consider only those most prevalent in the Delta. In earlier years practically the only method practiced was what is now termed "hand picking." In following this method the laborers were each given a box or a bottle and they depended entirely upon being able to see and capture the adult

weevils on the plants. This method was exceedingly slow and laborious and, owing to the large number of weevils actually overlooked, and the additional number escaping by "possuming" and falling to the ground upon the first disturbance of the plant, this method was not very effectual. Within the last few years, however, a semimechanical method of collection has been devised by some of the Delta planters and its use has spread rapidly. This is what is commonly termed the "bag-and-hoop," or "hoop-and-sack" method of collection. It consists of shaking the plants into a sack, the mouth of which is held open by a barrel hoop. This method proved to be much more effective and less expensive than hand picking.

To determine the relative efficiency of these two methods of weevil collection a number of comparative tests were conducted. These show the hand picking to require four times as long as the bag-and-hoop, while the latter collected more than twice as many weevils as the hand picking from the same area. In addition to this, in the course of the weevil collection with the bag-and-hoop a large number of infested forms are gathered, thus making the operation in reality a combination of weevil picking and square picking. Thus it can readily be seen that there is no question of the great superiority of the bag-and-hoop method over hand picking.

The apparatus required for the bag-and-hoop collections is the simplest possible. A burlap seed sack with a barrel hoop some 24 inches in diameter sewn into its mouth is all that is necessary. A tub or barrel of water with a small amount of kerosene on its surface may be placed on the turnrow and the bags emptied into it about every second row.

It was found that there was considerable difference in the results secured from the different methods of handling this bag-and-hoop. Comparative observations have shown the following to yield the best results: The bag should be placed against the base of the cotton stalk with as little disturbance as possible. Then the plant should be gently bent well into the mouth of the bag and shaken several times rather sharply from side to side, that is, at right angles to the length of the bag instead of back and forth into its mouth. It was found that there was considerable difference in the weevils collected when these two methods of shaking the plant were compared. As a result of shaking the plant lengthwise of the bag a number of weevils are evidently thrown away from the bag instead of into it, while other weevils actually thrown into the bag strike against the hanging back and bounce out again. On the other hand, when the plant is shaken across the sack, all weevils falling from it are retained.

More elaborate devices resembling the bag-and-hoop in principle were tested, but it was found that none of these was as efficient as

the simple form just described and that all possessed the additional disadvantage of being more expensive to make.

Observations were made to determine the time required per acre for the operation of the bag-and-hoop, and it was found to vary widely with the individual laborer, but the general range was found to be from 1 to 2 acres per hand per day. Of course the operation would be more rapid during the early pickings when the plants are small and weevils are rather scarce. The figures secured, however, seem to indicate that from 1 to 1½ acres per laborer per day is the best average that can be expected throughout the picking season. On a day-wage basis this would mean an average expenditure of some 40 to 60 cents per acre for each picking, and if the pickings were continued very late into the season this expense would be considerably increased.

The time interval between pickings which will yield the best results is still open to question, but it seems advisable to make it shorter than that between square pickings in order to reduce the time for square puncturing allowed the weevils, and also to reduce the number of infested forms falling to the ground between pickings, thus securing the benefit of both square picking and weevil picking. The studies to date seem to indicate that better results will be secured from several pickings given early in the season with a short time interval than where the same number of pickings are extended over a longer period by making the time interval a week or more. In fact, when the labor supply is not sufficient to allow this intensive treatment of all of the cotton it seems probable that better net results would be secured by concentrating the labor on only a portion of the crop and allowing the remainder to go untreated. In the case of cotton worked by wage labor the control measures could be concentrated on certain cuts, while in a case of tenant cotton the thorough and consistent picking of a portion of a cut would probably be more profitable than scattering the same amount of labor over the entire cut, in a series of more or less irregular and haphazard pickings. This concentration of effort, however, would not apply in a season of exceedingly heavy weevil infestation when the available food supply on the near-by untreated cotton would soon be exhausted and the weevils would migrate into the picked cotton in search of food. Except under these conditions, however, the early season interfield movement of weevils is apparently sufficiently slight to allow their control within a comparatively small area.

GENERAL CONSIDERATIONS.

The foregoing discussion has been devoted to the consideration of the best methods of picking weevils and squares, and the figures have been based on a day wage scale. There now remains to be considered

the application of these facts and figures to plantation conditions. In the first place there is little or no picking on a day wage basis, but it is practiced under the tenant system where no actual cash outlay is required and the only expense of the operations is that incurred by the detrimental effect produced on either the cotton or some other crop because of taking the labor from its care and utilizing it in these weevil control measures. Consequently, the question is just how much the planter can afford to slight the other operations in order to pick his squares or weevils. Studies on the increased yields produced by these control measures have shown that there is a very definite advantage. However, very little neglect of the cultural operations may produce a loss amply sufficient to more than offset any benefit derived from the reduction of the weevil infestation. For this reason it seems generally inadvisable to practice these control measures except in the presence of an abundance of labor.

Because of this complication with the labor supply the greatest desideratum at present is the perfection of a mechanical means of weevil picking which will be as effective as the bag-and-hoop method and still will allow the handling of a considerable number of acres per day per hand. Several mechanical devices were tested in comparison with the bag-and-hoop and, while none of them was as efficient as the latter method, one or two gave some promise of satisfactory results with further improvements in their construction. It should be stated that there are a number of serious problems to be met by a mechanical picker, which make it still doubtful as to whether a satisfactory one can be devised. In the first place the question of interruption of operations by rainy weather is a serious problem. A number of successive rainy days resulting in continually muddy fields produces the best possible conditions for weevil multiplication and thus necessitates even more strenuous efforts for control, but the same conditions make it difficult to operate mechanical pickers in the field. Such weather conditions are met with practically every spring in the Delta. The necessity for drainage in this region causes the cotton to be planted and worked on "ridges." This raising of the plants above the middle of the rows interferes seriously with the operation of many mechanical pickers. In addition to this, as long as the present system of laying off and planting rows is followed there will always be more or less crooked rows and the distances between the rows will vary considerably. This condition presents another obstacle to mechanical pickers, particularly those taking two rows at a turn. Still another obstacle is the difficulty in operating many of these machines in irregular, stumpy land such as is found on some parts of almost every plantation in the Delta. These fields are the ones which have been cleared only recently and

with proper protection from the weevils would make far better cotton crops than the land which has been in cultivation for a longer period. Considering these obstacles to be overcome and the degree of efficiency in weevil collection which must be developed by a mechanical picker, it is easy to see that there will be great difficulty in developing a satisfactory one.

One factor in the relation of these weevil-picking measures to the plantation complex is the effect upon the labor itself. On many plantations it is desirable to have the laborers conduct some direct control measures in order to encourage them to work the crop thoroughly. In such cases the bag-and-hoop method seems to satisfy the needs very well. The laborers can capture a considerable number of weevils and the fact that they are actually destroying these weevils often seems to encourage them greatly. In fact, a number of planters who practice this control measure state that they do not consider that they are deriving any direct benefit from the reduction in weevil infestation, but that the operation is worth while because of its beneficial effect upon the morale of their labor.

SUMMARY AND CONCLUSIONS.

Plat tests of five square pickings at seven-day time intervals gave an increased yield of 23 per cent over the check.

Tests of seven weevil pickings with the bag-and-hoop indicated similar results.

The seasonal conditions obtaining during the course of the experiments described in this bulletin have been referred to; it is possible that different seasonal conditions might yield different results.

Comparative observations on different methods of collecting weevils demonstrated the great superiority of the bag-and-hoop over hand picking so definitely that there should be no question as to which method to follow.

The margin of profit to be derived from these two control measures seems to be too slight to allow their operation on a wage basis. For this reason the only condition under which they should be attempted is on tenant cotton where the work can be performed without any direct outlay for labor.

Owing to the shortage of labor in the Delta these operations are very likely to interfere seriously with the regular plantation work and thus cause a loss more than sufficient to offset any benefit derived from them. In such cases it is not advisable to attempt to pick either squares or weevils.

In case it is necessary to choose between a cultivation and a weevil or square picking, cultivate.

If, after considering the foregoing points, it seems advisable to practice either of these control measures, the following seem to be the best methods:

Square picking.—A time interval of about seven days between square pickings seems advisable.

The first picking should be made within a week of the time when the squares start to fall in considerable numbers.

It is not likely to prove profitable to pick squares more than four or five times.

The squares should be disposed of as soon as possible after collection by burning or burying.

Weevil picking.—The most satisfactory method of weevil picking now known is the bag-and-hoop.

The first picking should be made as soon as the weevils are sufficiently abundant to make the operation worth while. This is likely to be about the time the plants start squaring or soon thereafter, although in exceptional cases it is not necessary to pick until considerably later.

Following this the pickings should be made as frequently as possible—twice a week, if practicable.

It is not likely to prove profitable to make more than four to six pickings at the most.

Of these two measures the bag-and-hoop is likely to prove the more profitable under usual conditions and is really the easiest and simplest method to practice.

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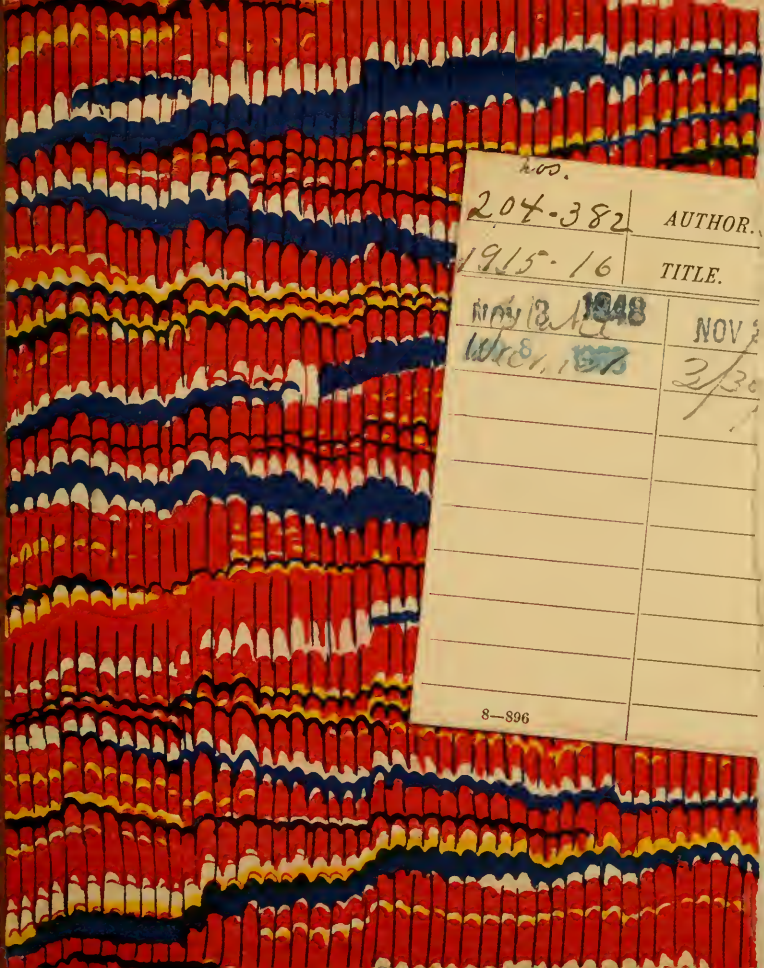
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